



Supporting Environmentally Sound Decisions for Bio-Waste Management

A practical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA)



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Executive summary

Overview

Approximately 120 to 140 million tonnes of bio-waste are produced every year in the EU¹. This corresponds to approximately 300 kg of bio-waste produced per EU citizen per year.

The definition of bio-waste is provided by the Waste Framework Directive (WFD)²: *“Bio-waste includes garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises as well as comparable waste from food processing plants. It does not cover forestry or agricultural residue.”* Bio-waste should not be confused with the broader category of “biodegradable waste”. Biodegradable waste, as defined by the Landfill Directive³, includes *“any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.”*

Throughout Europe, about 40% of bio-waste is still landfilled (up to 100% in some Member States)⁴. This is not in-line with the guiding principles of EU waste and sustainable resource management policy, notably the “waste hierarchy” that should underlie all national waste policies. According to the waste hierarchy as defined in article 4(1) of the WFD, waste prevention is the preferable option, followed by preparing for re-use, recycling and other recovery (e.g., energy recovery). Disposal (e.g., landfilling) is seen as the least desirable option.

However, article 4(2) of the WFD states: *“When applying the waste hierarchy referred to in paragraph 1, Member States shall take measures to encourage the options that deliver the best overall environmental outcome. Member States may depart from this hierarchy for specific waste streams, if this is justified by life cycle thinking on the overall environmental impacts of the different waste management options.”*

Generally, applying the waste hierarchy should lead to the waste being dealt with in the most resource-efficient way. However, as supported by Article 4(2) the WFD, Life Cycle Thinking (LCT) can be used to complement the waste hierarchy in order to make sure that the best overall environmental option is identified.

The Life Cycle Thinking (LCT) concept and quantitative tools such as Life Cycle Assessment (LCA) can provide an informed and science-based support to a more environmentally sustainable decision-making in waste management.

Life Cycle Assessment (LCA) is a structured and internationally standardised method that quantifies all relevant emissions, resources consumed/depleted, and the related environmental and health impacts associated with any goods or services.

¹ Communication from the commission to the council and the European parliament on future steps in bio-waste management in the European Union COM(2010)235

² Directive 2008/98/EC

³ Directive 1999/31/EC

⁴ Idem 1

When LCT/LCA are applied to waste management services, typically the assessments focus on a comparison of different waste management options, not covering the entire life cycle of the products which have become waste. Therefore, LCT/LCA applied to waste management services can differ from product LCT/LCA, which accounts for the entire life cycle of a product, in which waste management may play only a minor role. However, if one of the evaluated waste management options includes that materials are given back into the life cycle of a product, a product life cycle perspective has to be taken into account also in LCT/LCA for waste management services.

About this guidance document

This guidance document provides European, National and regional/local waste policy makers, waste managers, and businesses with the background to implement the WFD for bio-waste policy in a more sustainable way. This can be achieved by selecting the most environmentally sound waste management option for bio-waste.

This guidance document does not seek to be comprehensive. It outlines the key principles to improve the decision making process in bio-waste management by using LCT and LCA. Its main aim is to provide practical, yet structured guidance on how to identify the preferable environmental option for bio-waste management. In particular, a number of different options for bio-waste management are considered (e.g., composting, anaerobic digestion, incineration) and guidance is given on how to assess and compare their environmental performance using a life cycle approach.

There are already well-established, LCA-based results that can be transferred to similar situations. This guide provides some quick answers to simple questions based on these existing insights. When such general rules are not applicable, this guide helps the user decide if conducting an LCA is necessary and provides additional insights for how to perform the LCA. It is however noted that sometimes the choice of the environmentally preferable option for bio-waste management needs to be made considering the whole municipal solid waste stream, and not limited to the bio-waste stream.

This document builds on more general guidance documents also developed by Joint Research Centre (JRC) in cooperation with the Directorate General for Environment (DG ENV): the "Supporting Environmentally Sound Decisions for Waste Management - Technical Guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA) for waste experts and LCA practitioners" and, for the LCA methodology related aspects, the International Reference Life Cycle Data System (ILCD) Handbook.

Key target audience

This guide has been developed for policy makers and managers involved in the management of bio-waste, or involved in making decisions that could affect its generation. Some sections are also relevant for LCA practitioners working in the context of bio-waste management.

Remarks

This document focuses on the environmental aspects of waste management services. While economic, social/societal aspects are mentioned, no detailed guidance on how to include them is provided in this document.

The recommendations given in this document are intended to help model a limited set of typical waste management and treatment activities, focussing on those processes, parameters and impacts that typically matter most. However, the LCA/LCT results and conclusions cannot be generalised and it is the responsibility of the expert to judge whether existing studies and information are relevant and can thus be extrapolated to a new situation not covered in this LCA/LCT study.

Links to specific chapters of the International Reference Life Cycle Data System (ILCD) Handbook provided in this guidance refer to the current edition of the ILCD Handbook (Edition 1).

List of abbreviations

AD	Anaerobic Digestion
APC	Air Pollution Control
C/N ratio	Carbon/Nitrogen ratio (weight ratio)
CBA	Cost-Benefit Analysis
CC	Centralised Composting
CLO	Compost-Like Output
DeNox	NO _x removal technology
EPLCA	European Platform on Life Cycle Assessment
EWG	European Waste Catalogue
GWP	Global Warming Potential
HC	Home composting
ILCD	International Reference Life Cycle Data System
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCT	Life Cycle Thinking
LD	Landfill Directive
MBT	Mechanical-biological treatment
RDF ⁵	Refuse Derived Fuel
RRDF	Refined Renewable Biomass Fuel
SC	Selective Collection (source separated collection)
SLCA	Social Life Cycle Assessment
SRF	Solid Recovered Fuel (see "RDF")
WFD	Waste Framework Directive
W-t-E	Waste-to-Energy

⁵ RDF and SRF are fuels prepared from non-hazardous waste to be utilised for energy recovery in waste incineration or co-firing plants regulated under Community environmental legislation.

Contents

1	INTRODUCTION	1
1.1	Background	1
1.2	Objectives of this document	1
1.3	Who should use this document?	2
1.4	Link to other waste guidance documents	2
1.5	Remarks	3
1.6	What is Bio-waste?	3
1.7	Life Cycle Thinking and Assessment: an overview	3
1.7.1	Life Cycle Thinking (LCT)	4
1.7.2	Life Cycle Assessment (LCA)	5
1.7.3	LCA standards	9
2	BIO-WASTE: DEFINITION, LEGISLATION AND MANAGEMENT	10
2.1	Key definitions	10
2.1.1	Biodegradable waste and bio-waste	10
2.1.2	Classification of sources of biodegradable waste	11
2.1.2.1	Municipal biodegradable waste	11
2.1.2.2	Agricultural and industrial biodegradable wastes	12
2.2	European legislation related to biodegradable waste and bio-waste	12
2.3	Bio-waste management methods	14
2.3.1	Prevention	15
2.3.2	Collection schemes	16
2.3.3	Bio-waste treatment options	18
2.3.3.1	Anaerobic digestion	19
2.3.3.2	Composting	21
2.3.3.3	Mechanical Biological Treatment (MBT)	24
2.3.3.4	Incineration	26
2.3.3.5	Other options for energy recovery: Pyrolysis and Gasification	28
2.3.3.6	Landfilling	29
2.3.4	Outputs from treatment processes and avoided products	31
2.3.4.1	Overview	31
2.3.4.2	Quality of recovered products and related market outlets	33
2.4	Waste hierarchy and bio-waste management	34
3	SELECTING THE ENVIRONMENTALLY PREFERABLE OPTION FOR BIO-WASTE MANAGEMENT WITH LCT AND LCA	36
3.1	Approaching bio-waste management issues with LCT and LCA	36
3.2	General guidance	39
3.2.1	Overview and key principles	39
3.2.2	Prevention of bio-waste	43
3.2.2.1	Prevention of food waste	43
3.2.2.2	Prevention of park and garden waste	47
3.2.3	Management of contaminated bio-waste	49
3.2.3.1	Key principles	49
3.2.3.2	Discussion related to key decision criteria	51
3.2.4	Management of non-contaminated bio-waste	54
3.2.4.1	Key principles	54
3.2.4.2	Discussion related to key decision criteria	57
4	FURTHER RECOMMENDATIONS ON HOW TO PERFORM FULL OR SIMPLIFIED LCA	71
4.1	General simplification rules	71

4.2	Discussion on possible simplifications.....	72
4.2.1	What is the environmentally preferable option for biogas use?	72
4.2.2	What is the environmentally preferable option between incineration and MBT?	74
4.2.3	What is the environmentally preferable option between incineration and SC+AD?	75
4.3	LCA modelling limitations	76
4.4	Guidance to model specific modules.....	77
4.4.1	Impacts of collection.....	77
4.4.2	Biogas valorisation	78
4.4.3	Incineration.....	79
4.4.4	Landfill.....	81
4.4.5	Key methodological issues.....	82
4.4.5.1	Biogenic carbon	82
4.4.5.2	Time-limited carbon sequestration and time frames	82
ANNEX: RELEVANT EUROPEAN LEGISLATION AND POLICIES		84

List of Figures

Figure 1: Example elements within Life Cycle Thinking.....	4
Figure 2: Life Cycle Impact Assessment	6
Figure 3: Potential sources of biodegradable waste and bio-waste.....	11
Figure 4: Waste hierarchy applied to bio-waste.....	35
Figure 5: How to approach waste management issues and decision with a LCT-based approach.....	38
Figure 6: Overview of the guidance tree to support sound environmental decisions for the bio-waste management.	40
Figure 7: Estimated food waste generation (kg/capita/year) in the EU27	44
Figure 8: Guidance tree to support sound environmental decisions for the bio-waste management: Relevance of prevention – food waste.....	46
Figure 9: Guidance tree to support sound environmental decisions for the bio-waste management: Relevance of prevention – green waste	48
Figure 10: Guidance tree to support sound environmental decisions for the bio-waste management: contaminated bio-waste.....	50
Figure 11: Guidance tree to support sound environmental decisions for the bio-waste management: non-contaminated bio-waste (part I/II)	56
Figure 12: Guidance tree to support sound environmental decisions for the bio-waste management: non-contaminated bio-waste (part II/II)	66

List of Tables

Table 1: The five phases of Life Cycle Assessment plus reporting and review	7
Table 2: Municipal biodegradable waste types that contribute to bio-waste and related European Waste Codes (EWC).....	12
Table 3: Main treatment methods for bio-waste.....	18
Table 4: Recovered products, avoided products and remaining bio-waste streams.	31
Table 5: Aspects to be considered in bio-waste decision making.....	39
Table 6: Example of food waste differentiation in Austria	44
Table 7: Technical specification for the use of RDF in cement kiln	52
Table 8: Limits values for chemicals in RDF from RAL.....	53
Table 9: Degradation of organic substances	57
Table 10: C/N ratio of different types of waste	59

1 Introduction

Key target audience:

- Waste policy makers and waste managers on national and sub-national levels

Purpose:

- To present background, objectives and target audience of this document
- To provide an overview of Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA)

1.1 Background

A key objective of the European waste management strategy is to improve the environmental performance of bio-waste handling. The Thematic Strategy on the Prevention and Recycling of Waste (COM(2005)666) promotes Life Cycle Thinking (LCT) in waste policies in the EU and defines proposals to encourage and assist Member States in implementing this approach. This includes specific provisions in the accompanying proposal for the Waste Framework Directive (WFD - 2008/98/EC).

Life Cycle Thinking can be used to complement and refine the waste hierarchy for decision support in waste management. As stated in Article 4(2) of the WFD the ultimate goal of the Member States for waste management shall be to identify and implement the environmentally preferable option; to reach this objective, it may sometimes be necessary to depart from the hierarchy if, and only if, this is validated by Life Cycle Thinking.

This guide, developed by the Joint Research Centre (JRC) in cooperation with the Directorate General for Environment (DG ENV), provides guidance on how to take into account Life Cycle Thinking to help choose the best bio-waste management options. Guidance is also provided on how to recognise whether conducting a new LCA is needed or whether LCT-based criteria suffice.

The target audience is mainly EU, national and regional/local public administrators. These groups do not necessarily have extensive knowledge of LCT and LCA, and may require the use of associated criteria and support tools.

1.2 Objectives of this document

The objectives of this document are:

- To provide practical guidance on how to deal with bio-waste in an environmentally-sound manner;

- To help identify the key technical and management parameters that most influence the environmental performance;
- To help identify when a specific LCA study on bio-waste management should be conducted or when LCT-based criteria apply;
- To provide guidance on how to select the best overall environmental option for bio-waste management using a life-cycle approach;

Although this guidance document provides some key elements on how to approach bio-waste management issues with LCT and LCA, reading this document alone cannot be considered sufficient to be able to carry out an LCA according to the standards and good practices.

The recommendations given in the following chapters are intended to help modelling a limited set of typical waste management and treatment activities, focussing on those processes, parameters, impacts and elementary flows that typically matter most. This, however, cannot be generalised and it is the responsibility of the LCA expert to judge along relevant existing studies and other information. Details on this and other questions can be found in the "International Reference Life Cycle Data System (ILCD) Handbook, General guide on LCA - Detailed guidance⁶".

1.3 Who should use this document?

This guidance document is useful for policy-makers and managers involved in bio-waste management, policy development, or in a decision making process that could affect bio-waste generation. The targeted audiences are mainly waste policy makers and waste managers on national and sub-national levels.

1.4 Link to other waste guidance documents

This guidance document is part of a set of guidelines, all developed by the Joint Research Centre (JRC) in cooperation with the Directorate General Environment (DG ENV) and tailored to the needs of different target audiences. This set includes:

- "Supporting Environmentally Sound Decision for Waste Management – A technical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA) for waste experts and LCA practitioners".
- "Supporting Environmentally Sound Decision for Construction & Demolition (C&D) Waste Management – A practical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA)";
- The present document: "Supporting Environmentally Sound Decision for Bio-Waste Management – A practical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA)";

⁶ <http://lct.jrc.ec.europa.eu/assessment/projects>

1.5 Remarks

This document focuses on the environmental aspects of waste management services. While economic, social/societal aspects are mentioned, no detailed guidance on how to include them is provided in this document.

The recommendations given in this document are intended to help model a limited set of typical waste management and treatment activities, focussing on those processes, parameters and impacts that typically matter most. However, the LCA/LCT results and conclusions cannot be generalised and it is the responsibility of the expert to judge whether existing studies and information are relevant and can thus be extrapolated to a new situation not covered in this LCA/LCT study.

Although this guidance document provides some key elements on how to approach waste management issues with LCT and LCA, reading this document only is insufficient background to enable a person to conduct an LCA according to the standards and good practices.

1.6 What is Bio-waste?

As defined in the revised Waste Framework Directive⁷, bio-waste includes:

- Garden and park waste;
- Food and kitchen waste from households, restaurants, caterers, retail premises and comparable waste from food processing plants.

Bio-waste does not include forestry or agricultural residue and, thus, should not be confused with the wider term “biodegradable waste” as defined in the Landfill Directive (1999/31/EC), which also covers other biodegradable materials such as wood, paper, cardboard, sewage sludge, natural textiles.

1.7 Life Cycle Thinking and Assessment: an overview

The following sections provide an introduction on Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA). A more detailed presentation of the key aspects and methodological procedure related to LCT and LCA is provided in the more general “Technical guide to Life Cycle Thinking and Assessment in waste management for waste experts and LCA practitioners”.

⁷ Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives

1.7.1 Life Cycle Thinking (LCT)

Until recently, the focus for environmental improvement actions was on the process, i.e. minimising point sources of pollution, discharges to rivers, emissions from chimneys and so on. In business, this has often meant a strategy of reducing environmental impacts that is confined within the factory gates. These strategies have not considered consequences on upstream supply chains, product use or end-of-life. In Government, actions have focused primarily on the country or region governed, and not considered knock-on impacts or benefits that would occur in other geographies.

In both cases, if there is insufficient attention to the full life cycle (production / supply / use / end-of-life), overall environmental degradation and unwise resource use may result. Additional potential consequences are damaged reputations and impaired financial performance for the parties involved.

Life Cycle Thinking (LCT) is a conceptual approach that seeks to identify improvements and to lower the impacts of goods or services (products) at all stages of associated life cycles, from raw material extraction and conversion, product manufacture, through distribution, use and eventual fate at end-of-life.

The concept of Life Cycle Thinking helps to avoid the situation of resolving one problem while creating another. LCT avoids the so-called “*shifting of burdens*”, e.g., from one stage in the life cycle to another, from one region to another, from one generation to the next or amongst different types of impacts (Figure 1).

This type of approach demands more from the policy developer or environmental manager, in that she/he needs to look beyond his own practices and knowledge. However, it also offers the possibility of significant advantages from the knowledge gained – for example through identifying process efficiencies or good management practices.

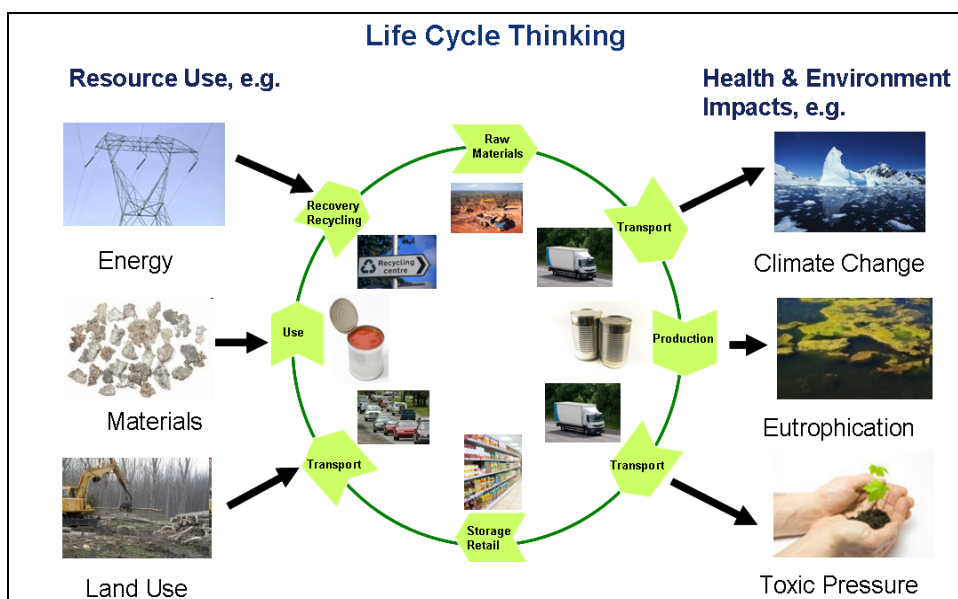


Figure 1: Example elements within Life Cycle Thinking

Figure 1 illustrates the correlation between the use of resources, the life-cycle, and the related environmental consequences. This is the most common application up to now. However, the LCT approach can equally be applied to non-environmental aspects (social, practical, economic, etc.), in order to deliver relevant information for a policy in line with sustainable development.

1.7.2 Life Cycle Assessment (LCA)

Life Cycle Thinking can be quantified in a structured, comprehensive manner through Life Cycle Assessment (LCA). In LCA, one assesses the emissions, resources consumed and pressures on health and the environment that can be attributed to different good(s) or service(s) taking into account their entire life cycle, from “cradle” to “grave”. LCA is an internationally standardised method (ISO 14040 and 14044)⁸ that can provide a rigorous approach for improving decision support in environmental management.

Using LCA, we seek to quantify all the physical exchanges with the environment, whether inputs of natural and energy resources or outputs in the form of emissions to air, water and soil. These inputs and outputs are compiled in a balance sheet, or life cycle “inventory” for a given “system”. After the inventory has been completed, the inputs and outputs are translated into indicators associated with different pressures such as resource depletion, climate change, acidification, or toxicity to plants, animals and people.

LCAs express environmental impacts per “impact category” or environmental problem. All emissions contributing to an environmental problem are converted into a common unit (e.g., kg CO₂-equivalent for climate change, or kg SO₂-eq. for acidification) using conversion factors (known as “characterisation factors”; e.g., for looking at climate change over a 100-year time frame, 1 kg of methane is equivalent to 25 kg CO₂⁹).

Figure 2 shows an example of this process – termed “life cycle impact assessment” (LCIA). Using scientifically-derived characterisation factors, the LCIA step calculates the relative importance of each input and output for the different types of environmental problem. Some of these characterisation factors are very reliable and globally harmonised for some impact categories (such as the IPCC factors used for climate change¹⁰), but for others (e.g., land use, toxicity) several methods exist and international/European harmonisation is ongoing¹¹.

⁸ http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_tc_browse.htm?commid=54854

⁹ Based on the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC); year 2006

¹⁰ Intergovernmental Panel on Climate Change (IPCC) 2006, Forth Assessment Report

¹¹ For more information please refer to <http://lct.jrc.ec.europa.eu/>

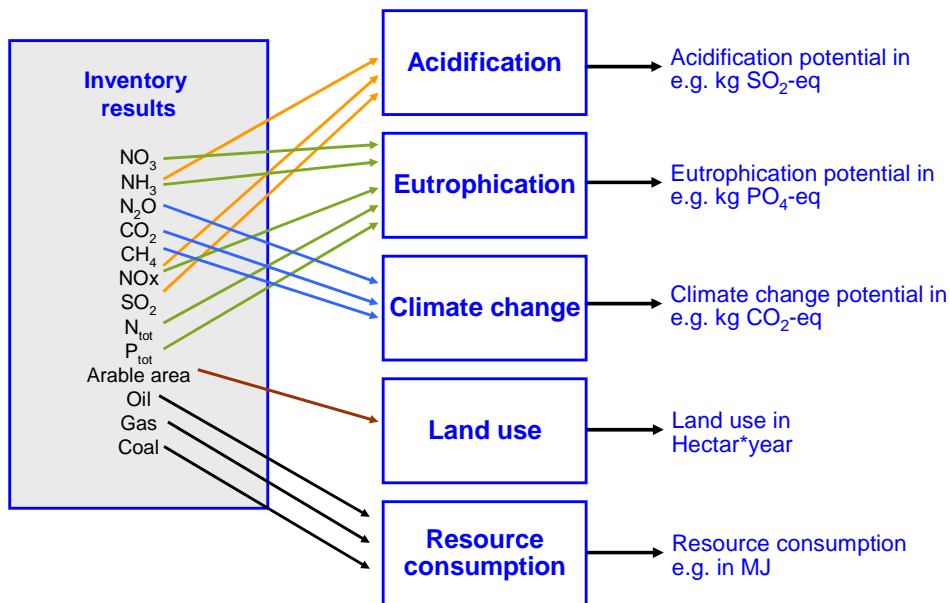


Figure 2: Life Cycle Impact Assessment

When LCT/LCA are applied to waste management services, typically the assessments focus on a comparison of different waste management options, not covering the entire life cycle of the products which have become waste. For example, when evaluating different options for bio-waste management, usually the production stages of the food that has become bio-waste, are not considered. Therefore, LCT/LCA applied to waste management services can differ from product LCT/LCA, which accounts for the entire life cycle of a product, in which waste management may play only a minor role. However, if one of the evaluated waste management options includes that materials are given back into the life cycle of a product, a product life cycle perspective has to be taken into account also in LCT/LCA for waste management services. For example, when looking at municipal waste management including recycling, the benefits of saving virgin raw materials in the production stages of products have to be taken into account.

LCA for waste management can be used for a range of applications, from assessing the benefits of avoiding a waste to evaluating different options for management systems. In the context of waste management facilities, an LCA considers the potential direct impacts of the operations on the environment (e.g., stack emissions from an incinerator). It also quantifies the indirect benefits of recovering materials and energy from the waste (e.g., through combined heat and power and ferrous metal recycling).

The results of an LCA can thus help businesses and policy-makers understand the benefits and trade-offs they face when making decisions on waste management options. LCA provides quantitative information which puts potential environmental advantages and disadvantages into perspective

When conducting a comprehensive LCA, first of all an independent review panel is chosen. Then, a five-phase procedure is followed:

- 1st phase: Goal definition;
- 2nd phase: Scope definition;
- 3rd phase: Life Cycle Inventory – LCI;
- 4th phase: Life Cycle Impact Assessment – LCIA;
- 5th phase: Interpretation of results.

These phases often involve iterations (mainly to improve data quality as necessary). Preparation of a draft LCA report follows completion of these five phases. The draft report is then submitted for review to the Review Panel. Preparation of the final LCA report should reflect analyses of reviewer comments and suggested revisions.

The following table (Table 1) provides an overview of the five-phase procedure for conducting LCAs; examples and key elements are provided for each phase. As shown in Table 1, a crucial task in the LCA scope definition is to identify the “**functional unit**”, i.e. the service or function the system being investigated delivers to the user. For example, in municipal waste management the functional unit can be collection and treatment of all household waste in a given region and year. All environmental burdens are then expressed relative to this functional unit. For comparing different waste management options, it is crucial that they provide the same function. Otherwise, a fair comparison between systems is not possible.

LCA is an iterative process. For example, one might need to revise the initial definition of goal and scope based on the findings of the inventory analysis, e.g., refine the system boundary to include a process that was initially disregarded.

Table 1: The five phases of Life Cycle Assessment plus reporting and review

Phase	Key Elements	Description
Goal	Six aspects of the goal definition	Identify the following -: <ul style="list-style-type: none"> • Intended application(s); • Proposed study methods, important assumptions and impact limitations (e.g., Carbon footprint); • Reasons for conducting the study, and the decision context; • Target audience; • Comparisons to be disclosed to the public; • Commissioner of the study and other influential actors.
	Classify the decision context	Identify the decision context: <ul style="list-style-type: none"> • Whether the study is interested in the potential consequences of this decision; • The extent of changes - further differentiates the decision-support cases into those that have only small-scale ramifications versus those that have large scale ramifications.

Scope	Define Function, Functional unit and reference flow	<ul style="list-style-type: none"> Identify the function of the subject product for both qualitative and quantitative aspects; Identify the reference unit for measurement and analysis.
	Life Cycle Inventory (LCI) modelling framework	<ul style="list-style-type: none"> Identify the LCI modelling approach according to the decision context.
	System boundary	<ul style="list-style-type: none"> Identify which processes are included and which processes are excluded.
	Preparing the basis for the impact assessment	<ul style="list-style-type: none"> Identify relevant impact categories
	Type, quality and sources of required data	<ul style="list-style-type: none"> Identify whether data quality is sufficient (in terms of data accuracy, precision / uncertainty and completeness of the inventory); Check whether all foreground and background data used in a LCI/LCA study are methodologically consistent.
	Comparisons between systems	<ul style="list-style-type: none"> Identify whether this study includes comparative assertions; Identify if the study includes comparisons and whether additional requirements are needed.
	Identifying critical review needs	<ul style="list-style-type: none"> Identify proper review type according to target audience and final deliverable.
	Planning reporting	<ul style="list-style-type: none"> Identify proper report type according to target audience and final deliverable.
Life Cycle Inventory	Planning data collection	<ul style="list-style-type: none"> Identify foreground and background data; Identify relevant processes; Identify relevant data; Design Data collection format.
	Collecting unit process	<ul style="list-style-type: none"> An actual collection of inventory data is typically only required for the foreground system; Describing what the modelled unit process represents; Collect relevant inputs and outputs of the unit process.
	Life Cycle Data Analysis	<ul style="list-style-type: none"> Select secondary LCI data sets; Filling initial data gaps; Solving multi-functionality of process.
	Calculating LCI result	<ul style="list-style-type: none"> Calculate and aggregate inventory data of a system.
Life Cycle Impact Assessment	Classification	<ul style="list-style-type: none"> Assign LCI results to the selected impact categories.
	Characterization	<ul style="list-style-type: none"> Calculate category indicator results.
	Normalization (optional)	<ul style="list-style-type: none"> Provide a basis for comparing different types of environmental impact categories (all impacts get the same unit).
	Weighting (Optional)	<ul style="list-style-type: none"> Assign a weighting factor to each impact category depending on the relative importance.
Interpretation and Quality control	Evaluation	<ul style="list-style-type: none"> Identify significant issues;
		<ul style="list-style-type: none"> Perform completeness check;
		<ul style="list-style-type: none"> Perform sensitivity check;
		<ul style="list-style-type: none"> Perform consistency check;
		<ul style="list-style-type: none"> Derive conclusion, limitations and recommendations;

		<ul style="list-style-type: none"> • Check if the LCA results fulfil the goal & scope of study
Reporting		<ul style="list-style-type: none"> • Is the quality sufficient?
Critical Review		<ul style="list-style-type: none"> • Are there potential for improvements?

1.7.3 LCA standards

The International Standards Organisation (ISO) 14000 series addresses environmental issues and includes 14040 and 14044 which relate to Life Cycle Assessment.

ISO 14040 and 14044 address not only the technical, but also the organisational aspects of LCA, such as stakeholder involvement and independent critical review of studies. Methodological aspects specify the general principles and requirements for conducting an LCA.

The European Platform on Life Cycle Assessment (EPLCA) and the International Reference Life Cycle Data System (ILCD)¹² promote the availability, exchange and use of coherent and quality-assured life cycle data, methods and assessments for reliable and robust decision support. The ILCD consists primarily of the ILCD Handbook and the upcoming ILCD Data Network, with the former setting requirements for quality of LCI data and LCAs and the latter providing access to data from a wide range of different data developers and on a global basis.

¹² <http://lct.jrc.ec.europa.eu/>

2 Bio-waste: definition, legislation and management

Key target audience:

- Waste policy makers and waste managers on national and sub national levels

Purpose:

- To provide a definition of bio-waste and biodegradable waste
- To present the key technical and management parameters for bio-waste treatment processes
- To present the key treatment options for bio-waste management

2.1 Key definitions

2.1.1 Biodegradable waste and bio-waste

Biodegradable waste is defined by Article 2 (m) of the Landfill Directive (1999/31/EC) as *“any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.”*

The revised Waste Framework Directive (2008/98/EC) defines bio-waste as: *“biodegradable*

- *garden and park waste,*
- *food and kitchen waste from households, restaurants, caterers and retail premises and*
- *comparable waste from food processing plants”.*

Biodegradable waste is a broader concept than bio-waste, as it does not only focus on waste from households and other streams that are supposed to produce similar waste, but also on other industrial streams.

Indeed, as mentioned in the Green Paper¹³: *“It does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. It also excludes those by-products of food production that never become waste.”*

¹³ Report on the Commission Green Paper on the management of bio-waste in the European Union [2009/2153(INI)] - Committee on the Environment, Public Health and Food Safety. Rapporteur: José Manuel Fernandes

2.1.2 Classification of sources of biodegradable waste

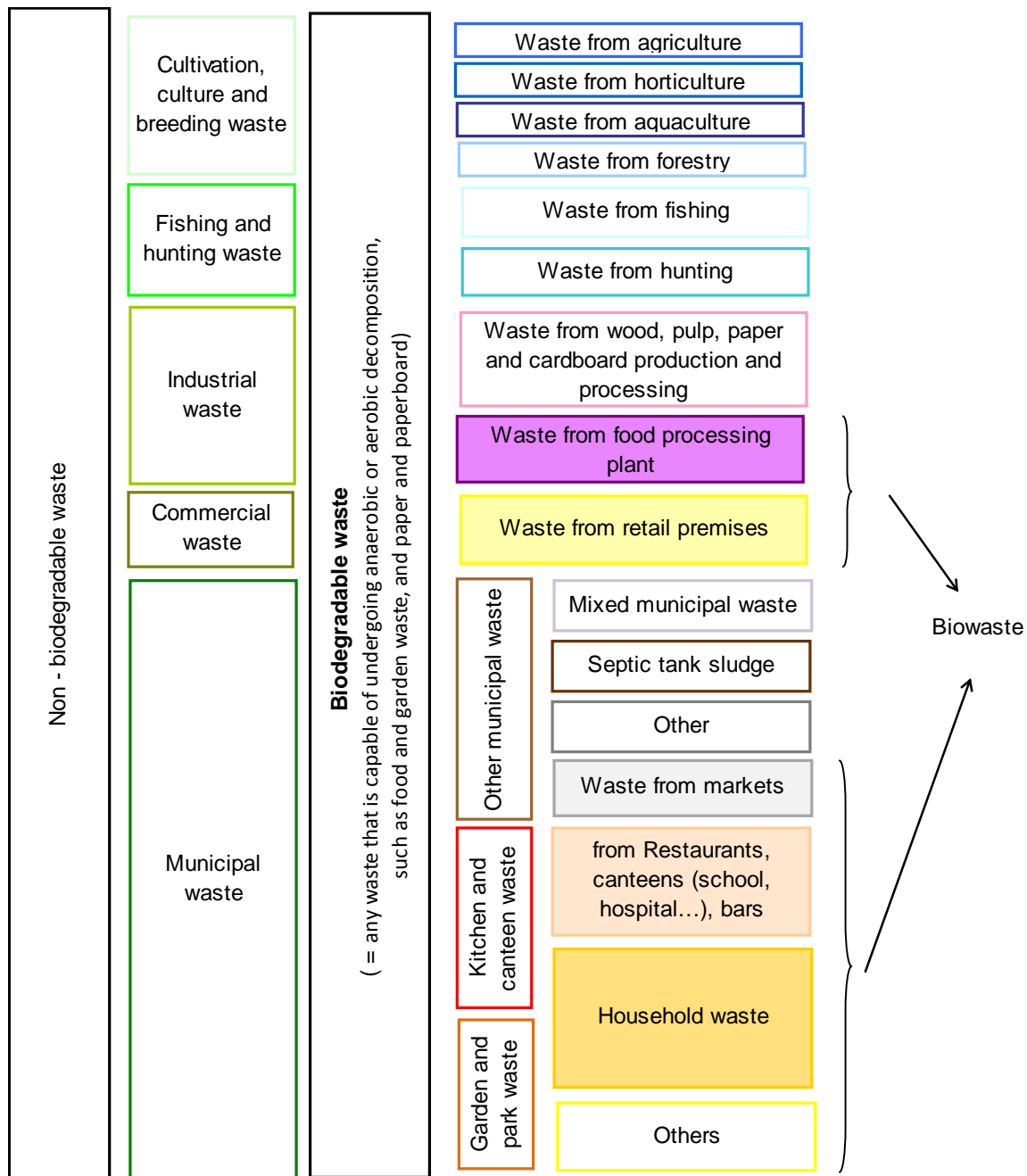


Figure 3: Potential sources of biodegradable waste and bio-waste

2.1.2.1 Municipal biodegradable waste

The municipal biodegradable waste streams that contribute to bio-waste are listed in the table below.

Table 2: Municipal biodegradable waste types that contribute to bio-waste and related European Waste Codes (EWC)¹⁴

Description	EWC code	Notes
Kitchen and canteen waste (food waste)	20 01 08	From households, restaurants, canteens, bars, coffee-shops, hospital and school canteens, etc.
Garden and park waste	20 02 01	From private gardens, and public parks and areas, etc.
Mixed municipal waste	20 03 01	Waste from households as well as commercial, industrial and institutional waste, which because of its nature and composition is similar to waste from households, but excluding fractions that are collected separately at source and excluding the garden and park waste
Waste from public markets	20 03 02	Only biodegradable materials equivalent to codes 20 01 08 and 20 02 01

2.1.2.2 Agricultural and industrial biodegradable wastes

This concerns "*comparable waste from food processing plants*" ("comparable" means comparable to Municipal biodegradable waste. Some types of industries generate non-negligible fraction of biodegradable waste¹⁵:

- Industries that use biomass for food;
- Industries that use biomass for non-food:
 - Textile industry
 - Leather industry
- Chemical and petrochemical industries.

2.2 European legislation related to biodegradable waste and bio-waste

The management of bio-waste is covered by several pieces of EU legislation (for more details see Annex: Relevant European legislation and policies).

¹⁴ Commission decision of 3 May 2000 (2000/532/EC) replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste

Commission decision of January 16, 2001 (2001/118/EC) amending Decision 2000/532/EC as regards the list of wastes

¹⁵ Based on: R. Gourdon (LAEPSI – INSA de LYON) (2002). "Aide à la définition des déchets dits biodégradables, fermentescibles, méthanisables", 153 p. Study performed for RECORD n°00-0118/1A.

The **Waste Framework Directive (WFD)**¹⁶ requires Member States to develop waste management policies that protect environmental and human health and ensure sustainable use of natural resources. Member States are legally bound to optimize the treatment of bio-waste according to their specific conditions.

Article 4 on the “waste hierarchy” states: *“the following waste hierarchy shall apply as a priority order in waste prevention and management legislation and policy: (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; and (e) disposal.”* *“When applying the waste hierarchy [...], Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste.”*

Generally, applying the waste hierarchy should lead to the waste being dealt with in the most resource-efficient way. However, in specific circumstances and for specific waste streams, deviating from the hierarchy may be necessary in order to select the best solution for the environment. Also, in many cases, a number of alternatives exist at a given level of the waste hierarchy (e.g., different recycling alternatives for a given waste stream). However, these alternatives are frequently not equivalent from an environmental perspective. This is why the WFD opens to deviations from the waste hierarchy if it can be justified by LCT that these deviations lead to improvements of the overall environmental performance.

The *Commission Communication on future steps in bio-waste management in the European Union*¹⁷ provides the steps that are considered necessary for improving the overall environmental performance of current bio-waste management strategies.

The WFD¹⁸ encourages Member States to collect separately and recycle bio-waste. Furthermore, the WFD enables the setting of EU minimum requirements for bio-waste management and quality criteria for bio-waste compost and digestate, including requirements on the origin of the waste and treatment processes. Such criteria have been introduced to enhance users’ confidence in using compost and strengthen the market in support to a material efficient economy.

The **Landfill Directive (LD)**¹⁹ requires Member States to progressively reduce landfilling of municipal biodegradable waste to 35% of the total municipal waste produced by 2016 (compared to 1995). Member States²⁰ that in 1995 relied heavily on landfilling for biodegradable waste management are given a 4-year extension period (i.e., until 2020). The objective of these measures is to reduce the emission of greenhouse gases from landfills.

¹⁶ Directive 2008/98/EC of the European Parliament and the of the Council of 19 November 2008 on waste and repealing certain Directives

¹⁷ COM(2010) 235

¹⁸ Directive 2008/98/EC of the European Parliament and the of the council of 19 November 2008 on waste, article 22

¹⁹ Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste

²⁰ Bulgaria, Cyprus, Czech Republic, Estonia, Greece, Ireland, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, UK

However, the LD does not prescribe specific treatment options for diverted biodegradable waste. In practice, Member States are frequently inclined to choose the seemingly easiest and cheapest option, sometimes disregarding the broader environmental (and social) consequences of this choice.

The **Directive on Renewable Energy Sources (RES)**²¹ also relates to bio-waste and encourages its use to replace fossil fuels. *“It sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport”* (Article 1).

2.3 Bio-waste management methods

A range of approaches are used for bio-waste management throughout Europe as mentioned in communication from the Commission COM(2010)235²²:

“Countries heavily relying on incineration of waste diverted from landfills, accompanied by a high level of material recovery and often advanced strategies promoting biological treatment of waste;

Countries with high material recovery rates but relatively little incineration, with some of the highest composting rates in the EU;

Countries relying on landfills, where diversion of waste from landfills remains a major challenge due to lack of established alternatives.”

On average, 40% of EU bio-waste is still landfilled in 2010 (up to 100% in some Member States). Big improvements have been made in the last decade in order to ensure better landfill management. However, landfilling (1) invokes major environmental risks such as emissions of greenhouse gases (methane) and pollution of soil and groundwater and, (2) withdraws valuable resources (compost, energy) irrevocably from economic and natural cycles.

Thus, it violates guiding principles of EU waste and sustainable resource management policy, notably the “waste hierarchy” which should underlie all national waste policies.

Bio-waste converted to treated compost (or digestate) contains elements (nutrients, lime, humus and organic matter) that lead to positive environmental effects (e.g., resource protection, soil protection, climate protection) when, the compost is used on land as, for instance, a replacement of fertilisers produced elsewhere. However, at the same time, bio-waste may possess characteristics that require appropriate solutions for its management, as listed in C. Saintmard (2005)²³:

²¹ Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources. The RES directive is adopted and in force; Member States transposed it on December 2010

²² Communication from the commission to the council and the European parliament on future steps in bio-waste management in the European Union (COM(2010)235)

²³ Caroline Saintmard (2005). Managing Biodegradable Household Waste: What prospects for European Local Authorities?.” Study performed for ACR+

- Easily contaminated by other substances;
- Unstable, source of nuisance, e.g., in the household bin (odours, percolation, etc.) and of pollution in landfills (emission of greenhouse gases, groundwater contamination and contamination of surface waters by leachate);
- A fraction in which moisture is variable, which has an influence on the logistical and technical requirements for its collection and further processing and also on the net calorific value.

2.3.1 Prevention

The Waste Framework Directive²⁴ defines waste prevention as: "*measures taken before a substance, material or product has become waste that reduce:*

- (a) the quantity of waste, including through the re-use of products or the extension of the life span of products;*
- (b) the adverse impacts of the generated waste on the environment and human health; or*
- (c) the content of harmful substances in materials and products "*

As per the Waste Framework Directive, prevention is the first priority. However, there can be some exceptions to the rationale of this priority for bio-waste that may require further analysis, which are identified by life cycle thinking.

One of the reasons bio-waste prevention may not be beneficial for the environment is that bio-waste management can lead to the production of energy and compost. Use of these recovered materials and energy can avoid the consumption of other resources including fossil fuels and other emissions to the environment that may, in some cases, otherwise be necessary. This explains why in some cases preventing bio-waste generation may not always be beneficial for the environment. Chapter 3.2.2 expands on the environmental consequences of bio-waste prevention.

There are two main methods to reduce bio-waste generation as part of waste prevention:

- Smart food consumption / food wastage²⁵ e.g. buying only what is needed, timely consumption, reducing waste in preparation, etc.

The annex of the communication from the Commission COM(2010)235²⁶ underlines that: "*A potential for preventing bio-waste exists mainly in the area of food waste. It is crucial to encourage households to see the potential*

²⁴ Directive 2008/98/EC

²⁵ Bio IS (2010) (in association with AEA Energy & Environment and Umweltbundesamt): Preparatory study on food waste across EU 27, interim report for European Commission DG-Environment

²⁶ Communication from the commission to the council and the European parliament on future steps in bio-waste management in the European Union (COM(2010)235)

savings. For instance, in the UK households typically lose around £680²⁷ annually for families with children on avoidable food waste [...] Waste prevention could imply a modification in consumer behaviour. Important changes could include a better “management” of food in households, better targeted purchasing decisions (“buy what is needed”), more attention and better information about the periods of product validity. Such measures would clearly not aim at reducing the Consumer's freedom of choice.”

The communication from the Commission COM(2010)235 also underlines that: *“In case of ambitious prevention policies up to 44 million tonnes CO₂-equivalent could be avoided (mainly from avoided emission related to food production and transport)”*.

- Smart gardening, e.g., choosing low-yield plant species, grass mulching.

Smart gardening mainly means choosing low growth plant species to lower the production of bio-waste and, therefore, the need to treat this bio-waste. As stated above, this is not (necessarily) advantageous for the environment. Grass mulching consists in cutting grass into very small pieces that fall on the soil and enrich the soil with organic matter while nutrients are sent back to the soil (local loop).

As supported by the COM(2010)235, home composting should not be regarded as a bio-waste prevention action. Indeed, home composting reduces the amount of organic waste contributing to municipal waste streams but, in practice, it has to be regarded as a local, decentralised treatment of waste.

2.3.2 Collection schemes

In addition to mixed waste collection, which severely limits the possible treatment options, different collection schemes are practiced for bio-waste. Source separated collection (source separated collection means only bio-waste is targeted, not plastics or other non-biodegradable (e.g. retail) waste), This can be organised in different ways:

- Door-to-door;
- Bring to centralised or decentralised (road/neighbourhood) container systems.

The decision whether a selective collection system should be introduced and the choice of the best system are crucial questions public authorities must answer. It is

²⁷ (500 M€ quoted in the communication). Value updated in 2009 in WRAP (2009) http://www.wrap.org.uk/retail/case_studies_research/report_household.html

up to Member States to determine whether separate collection of bio-waste is appropriate. This depends on:

- a. Adaptation of the collection schemes to the local context:
 - **Population density** is an important element since source-separated collection can be difficult to implement:
 - in highly-populated areas, i.e., due to insufficient space for storage of several waste streams inside home sorting as underlined in the annex of the COM(2010)235²⁸ may be ineffective, leading to lower amount and lower purity of the targeted selective stream, and
 - in very rural areas, i.e., great distances covered per amount collected (however, this plays a limited role in the overall impact)
 - **Climate** may play a crucial role in the decision of collection frequency. Depending on temperature and/or moisture, bio-waste collection will take place more or less frequently with the aim to prevent odour and hygiene problems. This is of course also valid for unsorted household waste.
 - **Existing legal framework** e.g. the Landfill Directive targets determine the need for alternatives to landfilling²⁹. If mixed waste is incinerated or treated with Mechanical-Biological Treatment (MBT) (stabilisation of organic matter), no selective collection is required. In other cases, both composting and anaerobic digestion need source separated collection.
 - **Potential amount of bio-waste that can be collected**
- b. Type of waste streams collected: garden waste, garden and food waste or food waste. Indeed, garden waste has characteristics that makes it very different from food waste, including:
 - A low putrescence and generally low moisture level;
 - Generally lower density;
 - A production rate that varies during the year;
 - A production that varies geographically.
- c. Downstream treatment options and existing collection, processing and disposal infrastructures
- d. Market for the compost (easier to find if good quality) and other recyclables (biogas, digestate, Refuse Derived Fuel)

²⁸ Communication from the commission to the council and the European parliament on future steps in bio-waste management in the European Union (COM(2010)235)

²⁹ The Landfill Directive sets diversion targets and leaves to Member states the choice of the method to achieve the target. The required efforts are obviously higher for Member States that heavily rely on landfilling of household waste.

2.3.3 Bio-waste treatment options

The treatment methods aiming at valorising the organic content of bio-waste on land work better with source separated waste, as the risk of contaminated bio-waste is too high when using mixed waste that is separated after collection. This does not apply to mechanical biological treatment, incineration and landfilling.

Table 3: Main treatment methods for bio-waste

Treatment method	Further characterisation
<i>For source separated bio-waste collection</i>	
Anaerobic digestion	Solid and liquid digestion with and without post-composting of digestate composting, efficiency of the energy recovery, dry or wet, mesophilic or thermophilic, continuous or discontinuous, 1-stage or multi-stage. Gains linked to energy production and use as fertiliser in agriculture
Composting	Open and closed types (pile, tunnel, composting in boxes/containers, etc.), centralised or home composting, type of ventilation system, maturation time. Gains linked to use as fertiliser in agriculture
Pyrolysis and Gasification	Mainly applied on dry streams, with the view of burning for energy recovery. They are intrinsically attractive technologies but still present technical challenges and cannot be considered as technically mature enough for bio-waste management. Could also be applied on mixed streams
<i>For mixed waste collection (i.e. bio-waste together with non-organic fractions)</i>	
Mechanical biological treatment	Is the pre-treatment to separate biodegradable waste followed by treatment similar to "source separated waste". Separation is based on mechanical properties. Possible treatments of organic fractions are: composting (stabilization), and anaerobic digestion with energy recovery. In case of AD, additional treatment of the digestate is needed (composting) before use as filling/covering material or before incineration
Incineration	Type of flue gas treatment. Efficiency of the energy recovery (energy recovery is currently widespread and even systematic in new plants)
Landfilling	The recovered landfill gas can either be burnt in flares or be recovered for energy (electricity and/or heat) generation

Pyrolysis and Gasification are much less applied than the other techniques. Incineration can also treat oversized rejects from green waste compost facilities (after selective collection).

For each of these treatment methods there are a number of essential factors that can influence environmental performance and must be considered. These will be explored in the following subchapters.

2.3.3.1 Anaerobic digestion

Background and principles

Anaerobic digestion is a process that breaks down organic matter into simpler chemical components without oxygen input, avoiding oxidation of the matter (under anaerobic conditions). This degradation process involves methanogenic bacteria which work at different temperatures and various pH values. Anaerobic digestion also generates considerable gas emissions (e.g., methane, ammonia, nitrous oxide) that need to be captured (and preferably used for energy recovery).

Anaerobic digestion may treat a wide range of organic waste streams including sewage sludge, municipal solid waste, and organic industrial, commercial and agricultural waste. Digestion of mixed waste renders it almost impossible to use the digestate as a fertiliser in agriculture because of the high risk of contamination. Digestion of separately collected bio-waste allows energy production and use of the digestate as a fertiliser in agriculture.

The high moisture content of kitchen waste and bio-waste from canteen, hotels and restaurants render these wastes particularly suitable for anaerobic digestion.

On the contrary, ligneous elements (green waste in particular) are typically not directly degradable by anaerobic digestion (not without resorting to a range of chemical/physical processes). However, it is possible to separate the wood fraction and use it as an energy carrier.

Technology and key parameters

The following factors are essential to have an efficient anaerobic digestion process (more details are provided in the study by ARCADIS 2010³⁰), but are not exhaustive:

- Temperature (T)³¹: the higher the temperature, the more effectively pathogens, viruses and seeds are destroyed. Other parameters also influence the efficiency of this destruction;
- Retention Time (RT)³²: it represents the time the feedstock spends in the digester: the longer, the better. The rate of the reaction is not constant, but decreases with increasing residence time. The “optimal” retention time depends on the feedstock and the operational parameters (in particular temperature);

³⁰ L. Franckx et al. (Arcadis/Eunomia) (2009). Assessment of the options to improve the management of bio-waste in the European Union. Study performed for the European Commission, DG Environment.

³¹ Caroline Saintmard (2005). Managing Biodegradable Household Waste: What prospects for European Local Authorities?”. Study performed for ACR+

³² M. Poliafico (2007). Anaerobic digestion: a decision support software. Cork Institute of Technology, Department of Civil, Structural and Environmental Engineering.

- pH: A pH value near neutral is the optimum for anaerobic digestion and below 6.8 methanogenic activity is inhibited³³;
- Ammonia concentration is a critical parameter. The optimum C/N ratio in anaerobic digesters is between 20 and 30, but it is less crucial than for composting);
- Water content (some so-called "dry processes"³⁴ run on solid substrates, i.e. with dry matter (TS) content between 15 and 45%);
- Mixing: Good mixing is required to obtain homogeneous optimal process conditions;
- Redox conditions;
- Content of lignin in waste.

An AD plant is more difficult to operate than a composting plant and requires skilled operators, mainly when the input material composition and/or the quantitative flow vary over time.

A range of different technologies for anaerobic digestion of organic waste exists, the digestion system can be:

- Dry, semi-dry or wet (containing typically <10%, 10-20% and 20-40% dry matter, respectively);
- Wet and semi-dry processes normally require stirred reactors and frequently treat a mixture of municipal organic waste, industrial organic waste and manure or sewage sludge. In dry anaerobic digestion, the municipal organic waste is often mixed with drier waste, e.g., garden waste, to obtain a good structure. The dry process may be batch wise or continuous (plug flow)³⁵.
- Continuous, semi-continuous or in batch;
- Semi-continuous systems aim to optimise digestion and improve control of the process in separating the stages of digestion;
- Thermophilic (49-60°C) or mesophilic (25-35°C);
- Thermophilic digesters might be more efficient (shorter retention times, higher loading rates and gas production, more effective sterilisation), but also require closer process control than mesophilic digesters.

The outputs are:

- **Digestate**, which is made up of fibres and liquid residues. The digestate can be:

³³ http://www.anaerobic-digestion.com/html/digester_ph_control.php

³⁴ E.g. Linde single-stage dry anaerobic digestion process

³⁵ Quantification of environmental effects from anaerobic treatment of source-sorted organic household waste. Trine Lund Hansen Ph.D. Thesis, Institute of Environment and Resources, Technical University of Denmark

- Directly used on land as fertilizer (e.g., digestate is often applied directly on farmland in Sweden). In this case, the organic matter is not stabilised or sanitised, which may lead to leaching of pollutants to soil. Digestate is a liquid fertiliser providing soil nutrients, but does not improve soil structure.
- Composted. This is necessary to sanitise the digestate and reduce the risk of toxicity to humans. The organic matter is stabilised and sanitised, leading to increased organic content of the soil. When the digestate is composted, the resulting compost is similar in quantity and composition to the compost from direct composting of bio-waste.
- **Biogas** is made of methane, carbon dioxide and water vapour (and possibly hydrogen sulphide). After possible treatment to remove hydrogen sulphide, it can be used as a source of energy to replace natural gas for the production of heat, electricity and as a fuel for vehicles (as a substitute for natural gas, gasoline or diesel);
- AD generates atmospheric emissions³⁶ (CH₄, N₂O, and other trace gases) that should be treated and inventoried in any LCA study.

2.3.3.2 Composting

Background and principles

Composting is the aerobic degradation of waste by micro-organisms and fungi to produce compost that can be used as a soil improver³⁷ and organic fertiliser. Due to the high temperature generated (55°C and more) by the process, harmful micro-organisms and undesirable seeds and weeds or roots are destroyed. Though CO₂ (of biogenic origin) is the main gaseous emission from the composting process, other gases are typically found including methane, ammonia and nitrous oxide. To reduce environmental impacts from composting, it is therefore important to minimise generation and emission of these gases, e.g., using biofilters.

³⁶ "Ermittlung der Emissionssituation bei der Verwertung von Bioabfällen." GEWITRA mbh. Forschungsvorhaben im Auftrag des UBA, Abschlussbericht Dezember 2008.

Cuhls C. und Mähl B., 2008: "Methan-, Ammoniak- und Lachgasemissionen aus der Kompostierung und Vergärung – Technische Maßnahmen zur Emissionsminderung." In: Bio- und Sekundärrohstoffverwertung III. Hrsg.: Witzenhausen-Institut für Abfall, Umwelt und Energie GmbH.

"Ökoeffiziente Verwertung von Bioabfällen und Grüngut in Bayern" ("Ecoefficiency of the recycling of bio-waste and greenwaste in Bavaria"), bifa-Text Nr. 47, bifa Environmental Institute, 2010): [http://www.bifa.de/index.php?id=148&show=detail&cid=174&mod=1&n=Ökoeffiziente Verwertung von Bioabfällen und Grüngut in Bayern](http://www.bifa.de/index.php?id=148&show=detail&cid=174&mod=1&n=Ökoeffiziente+Verwertung+von+Bioabfällen+und+Grüngut+in+Bayern)

³⁷ A. Smith, K. Brown, S. Ogilvie, K. Rushton and J.Bates (AEA Technology 2001). Waste management options and Climate Change. Study performed for European Commission, DG Environment.

The compost is considered as “mature” when it is stabilised, i.e., when any subsequent change to its texture and its composition is extremely slow.

Compost can have an added value on fields as it can improve soil structure and quality by adding organic matter, nutrients and a diversified biologic life (micro-organisms). The LCA modelling can either directly account for those benefits, or consider savings by avoiding the use of other materials like peat and fertilizers.

Technology and key parameters

The following factors affect the overall performance of the composting process, and should be carefully monitored (partly based on ARCADIS, 2010³⁸):

- Nature of the input waste, in particular the nature of the organic carbon (as this determines the actual biodegradability);
- Aeration (in order to maintain aerobic conditions within the whole composting mass and to avoid the formation of anaerobic pockets within the mass and to avoid odours): effectiveness of the turning, airflow systems, frequency of turning;
- Temperature (in order to degrade unwanted matter without destroying all microbiological activity);
- Moisture content and pH;
- C/N ratio of the bio-waste;
- Availability of a growing medium that provides living organisms the energy required for their development;
- Low content of potential pollutants (heavy metals, organic pollutants);

Besides this, valorisation of outputs also increases the environmental balance of the composting process: in particular, using the residual heat from composting is a promising new technique that might lead to an improved environmental profile.

The following aspects markedly influence the quality of compost:

- Separate collection is necessary to ensure the compost is uncontaminated
The composting process must operate continuously under aerobic conditions at optimum moisture content in order to provide favourable conditions for humus formation;
- Good control of the composting process (mainly optimum temperature) to ensure pathogen destruction.

³⁸ L. Franckx et al. (Arcadis/Eunomia) (2009). Assessment of the options to improve the management of bio-waste in the European Union. Study performed for the European Commission, DG Environment.

- Compost should undergo a sufficiently long maturation process. Due to the high temperature during a sufficient period, sufficient moisture and shifting conditions, harmful micro-organisms and undesirable seeds or weeds/roots are destroyed:
 - for mixed kitchen and garden bio-waste: composting at 45°C for 6 weeks, including at least 4 consecutive days at 60°C
 - for green bio-waste: composting at 45°C for 10 weeks, including at least 4 consecutive days at 60°C
- Compost must not contain toxic nor visible elements, like plastic particles;

As selective collection normally delivers pure organic, clean and not contaminated raw materials, compost usually contains a low amount of pollutants (heavy metals, organic pollutants).

It is possible to separate the wood fraction and use it as an energy source.

Mature compost is used in applications such as for peat substitution, mineral nutrient substitution, erosion control, increasing water-holding capacity, and organic matter content of the soil.

Composting of bio-waste fractions can take place in a number of different ways:

- **Home composting** is the "*composting of bio-waste as well as the use of the compost in a garden belonging to a private household*"³⁹. Recycling at the point of production has the advantage of avoiding the collection step and buying alternatives. On the other hand, it is necessary to ensure that the citizens have enough knowledge and commitment to compost their waste correctly, otherwise it can generate greenhouse gases such as methane and be environmentally problematic.

The most common home composting techniques are:

- Heap/piles;
 - Composting bins;
 - Silos or open boxes;
 - In-house worm composter;
- **Collective/Community composting** is the "*composting of bio-waste by a group of people in a locality with the aim of composting their own and other people's bio-waste in order to manage the supplied bio-waste as close as possible to the point at which it was produced*"⁴⁰.

³⁹ European Commission DG Environment (2001). Working document. Biological Treatment of bio-waste – 2nd draft.

⁴⁰ European Commission DG Environment (2001). Working document. Biological Treatment of bio-waste – 2nd draft.

- **On-farm composting** is the composting of bio-waste by a farmer that aims at using the compost-output to improve soil quality on the farm.
- **Centralised composting**

The most common techniques are:

- Windrow composting. This method is defined as the "*composting of bio-waste placed in elongated heaps, heaps of triangle or trapezoid cross-section which are periodically turned by mechanical means in order to increase the porosity of the heap to increase the active surface accessible to micro-organisms and increase the homogeneity of the waste*"⁴¹.

It can be done in the open air, but it presents risk of producing odours in the neighbouring area if not managed properly, as well as emitting other pollutants such as methane or micro-organisms. Centralised composting can of course also be conducted under semi-permeable covers or in enclosed buildings, allowing the operator to better control odours and other emissions.

- In-vessel composting. It is defined as "*composting of bio-waste in a closed reactor where the composting process is accelerated by an intensified air exchange and an automated temperature control*"⁴²." With in-vessel composting, exhaust gases can be collected and treated; the most common treatment technology being biofilters.

2.3.3.3 Mechanical Biological Treatment (MBT)

Background and principles

Mechanical-biological treatment (MBT) is a general term covering a variety of combinations of centralised mechanical separation systems linked to one or many biological treatment methods, which allow:

- Extraction of biodegradable waste for specific treatment;
- Pre-treatment of biodegradable waste to be landfilled, reducing its mass and stabilising it;
- Diversion of the biodegradable fraction from landfill.

⁴¹ European Commission DG Environment (2001). Working document. Biological Treatment of bio-waste – 2nd draft.

⁴² European Commission DG Environment (2001). Working document. Biological Treatment of bio-waste – 2nd draft..

Mechanical biological treatment is often used to reduce waste volume and mass and to stabilise the biodegradable fraction of MSW before it is landfilled. This in turn leads to reduction of landfill odours and of biogas generation and to generation of leachate with lower concentrations of organic matter and other pollutants. MBT is frequently employed to comply with the landfill Directive, i.e., to reduce the biodegradable fraction of waste going directly to landfill. The MBT process may lead to the generation of a variety of gaseous pollutants (e.g. methane, ammoniac, laughing gas), which makes it crucial to implement extensive emission control measures.

Technology and key parameters

MBT plants combine several types of waste treatment (i.e., sorting, biological treatment, etc.).

The biological process in the MBT can be:

- **Aerobic:** the process is conducted as a classic composting process (on selected organic fractions);
- **Anaerobic:** the biological process consists of a fermentation stage producing biogas and a digestate that can be composted (as the digestate from AD on selective flows), but cannot be used for soil improvement. Application of anaerobic digestion to bio-waste derived from mechanical sorting of mixed waste has often proved to be very critical for the process itself (clogging of the reactor due to inert materials, etc.). Therefore, most often composting is preferred.

The following outputs can be recovered from MBT facilities:

- Compost, not suited for application on soil because of the high contamination risk; this is more likely to be called Compost-Like Output (CLO). The organic fraction is bio-stabilised. This has the advantage of reducing biodegradation inside the landfill and the associated odours and methane emissions;
- Recyclable materials (e.g., metals, plastics), containing more impurities than materials from selective collection (of packaging);
- Biogas (in case anaerobic digestion is applied). However, application of AD to “dirty” bio-waste, i.e., to that derived from mechanical sorting of mixed waste, has often proved to be very critical for the process itself (clogging of the reactor due to inert materials, etc.);
- Refuse Derived Fuel (RDF), i.e., pellets of fluff with high caloric value, for energetic valorisation.

2.3.3.4 Incineration

Background and principles

Incineration is a waste treatment method that involves combustion of waste material. It is used to treat of solid and liquid wastes. Incineration is further described according to the type of waste incinerated:

- Mixed municipal and similar industrial and commercial waste incineration;
- Hazardous waste incineration (such as biological medical waste);
- Sewage sludge incineration;
- Pre-treated municipal or other pre-treated waste incineration (RDF), although it is usually intended for co-combustion;

The objective of waste incineration, common to most waste treatments, is to treat waste to reduce its volume and hazard, whilst capturing (and thus concentrating) or destroying potentially harmful substances. In the case of bio-waste, there is (almost) no residue from incineration (it is fully combustible or evaporable (water)).

Incineration processes can also provide a means to enable recovery of the energy, mineral and/or chemical content from waste. The heat produced by the combustion is nowadays extensively recovered, by producing steam that can be converted into hot water (for heating purposes), steam (industrial processes) and electricity. The process (fans, electrofilters pumps, etc.) consumes about 10% of the energy produced.

Waste-to-Energy (W-t-E) is a term applied to facilities that burn waste in a highly engineered furnace. Heat from this process is used in the boiler to produce steam and afterwards to generate electricity and/or heat. Combustion in W-t-E plants may generate a broad range of gaseous pollutants, including micro-pollutants and some toxic and persistent organics (e.g., dioxins, furans, PAHs, PCBs). Their origin is either a direct transfer (with carbon oxidation) from the waste incinerated (e.g., CO₂, metals, and halogens), or the result of an incomplete combustion, containing both elements from the air and from the waste (CO, NO_x, micro-pollutants, etc.). Current technology can maintain stack emissions well below current emission limits (Directive 2000/76/EU), thus, minimizing negative environmental impacts, as well as adverse effects on human health.

Incineration also produces solid residues:

- Bottom ash: Ferrous (iron, steel) and non-ferrous metals (such as aluminium, copper and zinc) are extracted from the bottom ash. After extraction of metal objects and further processing, bottom ash can be used as secondary raw material, e.g., in road construction, as a foundation material (conditions are to be respected to avoid leakages of potential toxic substances), in noise barriers, as a landfill capping layer and in some countries as an aggregate in asphalt and concrete. In practice, this does not concern bio-waste as bio-waste as such is fully burned and produces no bottom ash (only some fly ash).
- APC residues⁴³: A solid residue separated from the incinerator flue gas. APC residues composition depends on the design and operation of the flue gas treatment plant. Typically, APC residues consist of one or more of the following components: fly ash, boiler ash, activated coal, flue gas cleaning reaction products and unreacted flue gas cleaning chemicals. To avoid negative impacts of the APC residues on the environment, they have to be managed or treated in specific ways. Some of these gas cleaning residues can be partially recovered to produce secondary raw materials for the chemical industry (e.g., sodium bicarbonate).

Incineration is carried out at industrial scale by private, generally in cooperation with public authorities, and public entities. Plant capacity of existing MSW (municipal solid waste) incineration plants ranges from 3 700 to 800 000 tonnes/year (although the tendency is to have larger plants, with a minimum capacity of 30 000 tonnes/year).

Technology and key parameters

The overall environmental performance of an incineration plant is highly variable and depends on aspects such as emission levels, energy recovery efficiency, type of energy that is substituted by the energy produced from the incineration process, amount and type of residues, distribution of pollutants among air emissions, water emissions (if any⁴⁴) and residues. Those specific values depend on:

- Waste composition: the net calorific value is perhaps the single most important waste-specific parameter;
- Emission control technology, e.g., type of flue gas cleaning and neutralising agent, deNO_x. Stack emissions are regulated by the Waste Incineration Directive (2000/76/EC);
- Energy balance;
 - Energy recovery efficiency

⁴³ Management of APC Residues from WTE Plants” An overview of important management options. The report is produced by ISWA, WGTG (Working Group Thermal Treatment)

⁴⁴ In many countries, plants are required to evaporate their wastewater in the Flue Gas cleaning, hence, ensuring that no water is discharged to the environment.

- Type of energy recovered: electricity and/or heat and steam, which can be used in an industrial process
 - Which alternative energy production system (resource) is substituted
- Efficiency of material recovery (steel, aluminium, solid inert material).

2.3.3.5 Other options for energy recovery: Pyrolysis and Gasification^{45,46}

A wide range of emerging thermal treatments exist for the treatment of municipal waste (not only bio-waste), Pyrolysis and Gasification being perhaps the most promising at this time.

Pyrolysis is a thermal process where the organic fractions in the waste are broken down in the absence of oxygen and under pressure. The process efficiency increases for increasing content of carbon in the waste input. Also, it is important that the waste input is selectively collected, so that most of the non-organic components are removed and the waste is homogeneous. The Pyrolysis process produces both a liquid residue and gaseous output; the latter may be combusted to generate electricity. In addition, a solid char is produced which may require disposal (e.g., landfilling) or additional processing (e.g. gasification).

Gasification requires the addition of an oxidant (e.g. air or oxygen) and typically operates at a higher temperature than pyrolysis. The solid char output from a pyrolysis plant may be fed into the gasification process. Gasification of organic waste (e.g. bio-waste) generates a gas that can be burnt to generate electricity and a char. The latter may be used as secondary construction material, thereby substituting virgin materials; if no markets are available, it usually requires disposal.

These technologies still present technical challenges and are not as extensively applied as e.g. incineration or composting. Some of them are still in a pilot stage and experiences with large scale facilities (e.g. with an annual capacity of ~10.000 tonnes) may be limited. Extensive and robust data-sets on pyrolysis and gasification plants is therefore still limited, which in turn does not allow conducting extensive assessment of their actual environmental performance. However, pyrolysis and gasification of waste are generally expected to become more widely used in the future. A main reason for this is that public perception of waste incineration in some countries is a major obstacle for installing new incineration capacity.

⁴⁵ Klein A., Whiting K., Archer E. & Schwager J. (2004). Gasification and Pyrolysis: what is the current situation for waste management? *Waste Management World*, 2004 71-75

⁴⁶ Malkow T. (2004). Novel and innovative pyrolysis and gasification technologies for energy efficient and environmentally sound MSW disposal. *Waste Management* 24, 53-79

2.3.3.6 Landfilling

Background and principles

Manfredi & Christensen (2009)⁴⁷ state that: “Conventional landfilling typically relies on anaerobic degradation of waste. Typical technical measures implemented include bottom liner, top soil cover, gas and leachate collection and treatment systems. Although these technical measures can significantly reduce the uncontrolled release of gas and leachate, potential environmental impacts still remain high, and threats to the environment exist far beyond the time frame of a generation. New, “active” waste landfilling technologies have therefore been developed in the last couple of decades, including bioreactor and semi-aerobic technologies with the aim of minimizing environmental impacts from landfilling.”

New technologies reduce the duration of active operations required at the landfills. In addition, active landfill technologies (i.e. leachate recirculation, waste flushing and air injection) often use the collected gas for electricity and/or heat generation, thus bringing environmental benefits compared to older technologies (the overall environmental value changes according to the efficiency of energy recovery).

However, it should be stressed that landfilling of biodegradable waste is an option that can only be employed as an interim solution as European legislation will progressively divert more and more organic matter away from landfills (Directive 1999/31/EC).

Technology and key parameters

The following parameters play an important role in determining the environmental performance of biodegradable waste landfilling:

- Landfill gas generation is related to the:
 - Carbon content of the waste;
 - Carbon degradation rate, faster for sugars than for lignin and some cellulose⁴⁸;
 - The specific degradation condition, e.g., redox conditions, availability of water and nutrients, presence of compounds that could inhibit the degradation process, degree of compaction of the waste.
- Landfill gas capture:

⁴⁷ S. Manfredi and T.H. Christensen (2009). Environmental assessment of solid waste landfilling technologies by means of LCA-Modeling. Waste Management 29 (2009) 32-43

⁴⁸ Indeed as mentioned in Arcadis/Eunomia report (2009), some cellulose is bound within the lignin and is therefore similarly resistant to degradation.

The Arcadis/Eunomia report (2009)⁴⁹ states that: *“For landfill gas capture a distinction can be made between instantaneous collection efficiency and the gas captured over the lifetime of the landfill.[...] Whilst instantaneous collection rates for permanently capped landfilled waste can be as high as 90%, capture rates may be much lower during the operating phase of the landfill (35%) or when the waste is capped with a temporary cover (65%). In addition, gas collection is technologically impractical towards the end of the site’s life.”*

Proportion of the gas captured that is used for energy generation: As underlined in the Arcadis/Eunomia report (2009)⁵⁰: *“It is usual for landfill operators to maximise energy generation as this represents a revenue stream”*

However, the report also highlights that:

- *“At times of high flux, emissions can be greater than the capacity of the engines and, thus, a proportion of the gas must be flared”*
- *“At times of low flux, i.e., towards the end of the site lifetime, emissions may be too small for the gas engines to function effectively*

This last case remains throughout the post-operative life of the landfill site (the long tail of landfill gas production).

Therefore, generated gas can be:

- Flared (CH₄ is converted to CO₂-biogenic);
- Recovered to produce energy (heat, electricity, or combined heat and power (CHP));
- Released to the atmosphere (CH₄ is emitted to the atmosphere; some of it will be converted into CO₂-biogenic due to interaction with O₂ in the air).

In any LCA including landfill operations involving bio-waste, key aspects include biogas production, capture efficiency and gas use to produce energy. Efficient gas capture and recovery allow for more energy production (and resource saving) and less methane emissions that would contribute adversely to climate change. Thus, the positive effect of a good landfill gas capture system on climate change is doubled. Moreover, a good capture system ensures fewer odours. As a result, it is important to use appropriate technologies to reduce the negative environmental impacts from fugitive gas releases as far as possible.

⁴⁹ L. Franckx et al. (Arcadis/Eunomia) (2009). Assessment of the options to improve the management of bio-waste in the European Union. Study performed for the European Commission, DG Environment

⁵⁰ L. Franckx et al. (Arcadis/Eunomia) (2009). Assessment of the options to improve the management of bio-waste in the European Union. Study performed for the European Commission, DG Environment

- Leachate:
 - Leachate generated;
 - Leachate collected (% of generated) and sent to a treatment plant (% of collected);
 - Leachate not collected and thus emitted to, e.g., soil, surface water bodies, ground water (% of generated);

- Land use:

Landfilling takes up land which cannot then be used for other purposes. It is widely agreed that landfilling is not a sustainable option for the future because of the negative environmental consequences. It can be a suitable interim solution under specific circumstances, until ecologically preferable bio-waste management options can be fully established.

2.3.4 Outputs from treatment processes and avoided products

2.3.4.1 Overview

Bio-waste management often produces recycling products (e.g., compost and digestate) and energy. These products avoid the use of other products (thus avoid the emissions that would be required to produce them). This generally results in positive environmental effects, depending on the recovery processes.

Table 4 lists the recovered products, energy recovery and related avoided products from bio-waste management. The different types of residues are also listed.

Table 4: Recovered products, avoided products and remaining bio-waste streams

Treatment method	Recovered products	Avoided products	Remaining waste
<i>For source separated bio-waste collection</i>			
Composting	Digestate	Growing media (e.g., peat), fertilizer, conditioner	Residues / impurities
Anaerobic digestion	Biogas Digestate (may be composted)	Electricity, heat, fertilizer, vehicle fuel	Residues / impurities

<i>For mixed waste collection (i.e., bio-waste together with non-organic fractions)</i>			
Mechanical biological treatment ⁵¹	Biogas RDF ⁵² CLO ⁵³	Electricity, heat, soil covering, recyclable materials	Stabilized waste or digestate (to be composted) Residues / impurities Recyclable materials, such as metals and some plastics
Incineration	Energy	Electricity, heat, (also bottom ash used as secondary construction material and metals, but not from bio-waste).	Residues
Landfill	Biogas	Electricity and/or heat (if there is methane recovery, depending on landfill equipment), legal and illegal dumping	Leachate

The amount of residues/impurities is rather small compared to the amount of bio-waste treated. In fact, residues/impurities are not inherent components of the bio-waste stream, but the materials that were comingled with the bio-waste since they are not the targeted stream.

As illustrated in Table 4, the range of products recovered from the treatment of bio-waste is relatively wide:

Compost can be used either:

- On Agricultural fields, where it plays different roles:
 - Soil fertiliser (bringing nitrogen, phosphorus or potassium to the soil),
 - Soil conditioner (transferring specific physical properties to the soil, through the building of the organo-mineral complex in the soil),
- On other soils, as growing media (soil substrate) in:
 - Green areas, forestry
 - Horticulture (nurseries, greenhouses, etc.)
 - For home/ hobby gardening

Digestate (from AD) that can be either:

⁵¹ There is also MHT (Mechanical Heat Treatment - autoclaving), a pre-treatment technology, mainly used to sterilise certain hospital type wastes (clinical waste). It works in a pressurised sealed drum under the action of steam.

⁵² RDF stands for Refuse Derived Fuel

⁵³ CLO stands for Compost-Like Output

- Directly used as fertiliser on field, or
- Composted to obtain compost (there is ongoing discussion whether composting of digestate produces compost similar in composition and quantity to compost from direct composting).

Compost-like output (CLO) has an extremely high risk of being contaminated. In Germany, the treated organic fraction from MBT (i.e., CLO) must be landfilled to avoid negative effects on the environment and human health. There is no environmental benefit. CLO can also be used as temporary soil coverings (e.g., for landfills), for green areas along motorways and railways. In this case, the environmental benefit is likely to be very small.

Biogas can be used:

- For heating;
- In combined heat and power (CHP) units;
- As a fuel for vehicles. This application requires the same type of engine as those used for natural gas. However, the biogas will have to be upgraded: the methane content needs to be increased to 95% and the gas should then be compressed. Biogas can be used either as a substitute for natural gas (no additional car driven by natural gas) or as a substitute for gasoline or diesel (additional cars driven by natural gas);
- As upgraded biogas injected into the gas grid or liquefied and transported to be used as a substitute of natural gas.

2.3.4.2 Quality of recovered products and related market outlets

The fraction of the treated bio-waste that will be turned into actual recycling products and energy recovery depends on the quality and composition of the initial bio-waste.

This is especially the case for recovered products, such as CLO coming from MBT facilities. Indeed, the quality of recovered products from these types of facilities is often poor because:

- They manage mixed waste (not just mixed bio-waste), hence, rising the level of contamination;
- They were primarily constructed to separate the organic fraction of household waste before landfilling;
- The processes are often undersized and operation is not optimised towards material recovery.

Therefore, the main challenges for this type of treatment plants are:

- The **quality of recovered products**, e.g., in the case of compost-like output applications where the level of contamination (i.e., heavy metals, visual contamination by small plastic particles, etc.) is higher relative to other types of compost produced from separated collected waste;
- The **attractiveness**, e.g., in the case of fuel applications, Refuse Derived Fuel (RDF) is simply less attractive to users than other fuels due to a mix of technical, economic, legal and regulatory reasons. But economic (price of fuels, CO₂ emission trading schemes, landfill tax), legal and regulatory (Landfill Directive, Renewable Energy Sources Directive) aspects can also encourage the use of RDF⁵⁴. In addition, there are also some concerns about the possible corrosion problems (due to Cl) in co-combustion boiler and other technical issues.

In order to gain the confidence and trust of the final users of end-products and to obtain higher environmental benefits, the development of product standards (for compost) and quality assurance systems are needed.

2.4 Waste hierarchy and bio-waste management

Most decision-makers agree with the new Waste Framework Directive (WFD)⁵⁵ that waste management strategies should follow legally binding priority order of the waste hierarchy: prevention, preparing for re-use, recycling, other recovery and, as the least desirable option, disposal.

Generally, applying the waste hierarchy should lead to the waste being dealt with in the most resource-efficient way and the decision-making process is easy, fast and cost effective.

However, in specific circumstances, there may be a need to deviate from the hierarchy in order to select the best solution for the environment. Also, a number of alternatives can exist at a given level of the waste hierarchy (e.g., different recycling alternatives for a given waste stream) which may not be equivalent from an environmental perspective.

In any case, as stated in the WFD, deviations from the priorities order set by the waste hierarchy can be accepted only if by Life Cycle Thinking it can be shown that these deviations have positive environmental consequences. In this respect, the WFD (Article 4) states that: *“When applying the waste hierarchy [...], Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste.”*

⁵⁴ Garg, A., Smith, R., Hill, D. Simms, N., Pollard, S. (2007). Wastes as Co-Fuels: The Policy Framework for Solid Recovered Fuel (SRF) in Europe, with UK Implications. Environ. Sci. Technol. 41, 4868-4874

⁵⁵ Directive 2008/98/EC of the European Parliament and the of the council of 19 November 2008 on waste and repealing certain Directives

The figure below (Figure 4) shows how the waste hierarchy could be applied to bio-waste management. It must be highlighted that, in principle, a number of other options for treatment of bio-waste could be placed in the figure. These include promising technologies such as pyrolysis and gasification. However, these technologies still present technical challenges and are not as extensively applied as e.g. incineration or composting. Some of them are still in a pilot stage and experiences with large scale facilities (e.g. with an annual capacity of ~10.000 tonnes) may be limited. Consequently, the availability of robust data on these technologies that can be compared with data from well established technologies is limited, which makes it difficult to conduct a detailed LCA and to assess their overall environmental performance, especially in comparison to well established technologies.

Exclusion from Figure 4 and difficulties to assess new technologies, nor even their initial performance relative to more established technologies, must not be misunderstood as a barrier to innovation (new technologies are explicitly welcome and encouraged). However, care has to be taken if technologies with different maturity are to be compared against each other. Any comparison has to be based on data of similar quality and availability.

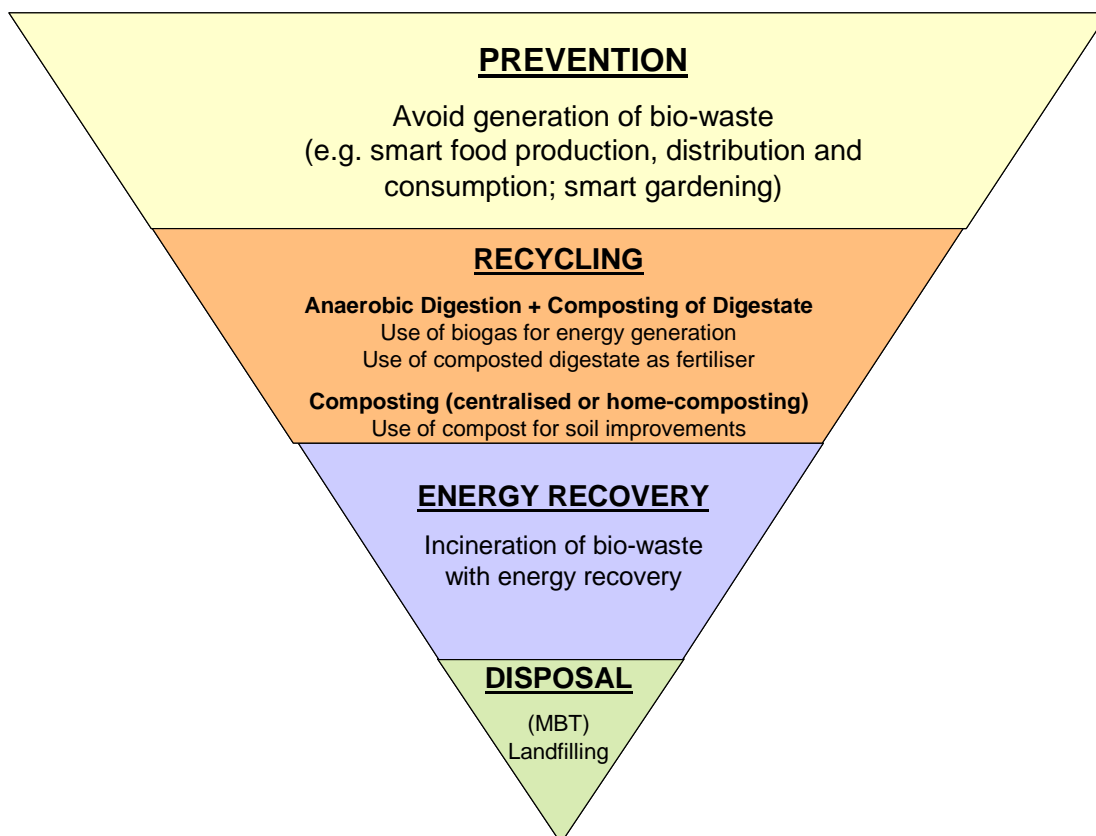


Figure 4: Waste hierarchy applied to bio-waste

Chapter 3 applies this general principle to guide waste managers to select the preferable bio-waste management system from an environmental perspective.

3 Selecting the environmentally preferable option for bio-waste management with LCT and LCA

Key target audience:

- Waste policy makers and waste managers on national and sub-national levels
- LCA experts in the area of waste management

Purpose:

- To help approach bio-waste management issues with LCT and LCA to identify the environmentally preferable option
- To provide practical guidance to policy makers and waste managers on how to deal with bio-waste in an environmentally sound manner

3.1 Approaching bio-waste management issues with LCT and LCA

A simplified decision-tree is here provided (Figure 5) to give guidance on how to approach and address waste management issue with LCT and LCA. The next paragraphs expand on how to interpret and use this decision tree. However, for a detailed explanation of the single steps, reference shall be made to the more general “Technical guide to Life Cycle Thinking and Assessment in waste management for waste experts and LCA practitioners”.

As the decision-tree shows, the starting point is the recognition of the fact that waste management decisions are to be taken. These should then be formulated in a way that provides a clear description of the alternative waste management options available, especially with focus on their potential environmental consequences.

In order to support environmentally sound decision-making for bio-waste management, the waste hierarchy, i.e. the legally binding priority order established by the Waste Framework Directive, should be considered.

If the waste hierarchy does not help to unambiguously identify the preferable option, it can then be evaluated whether evidence from previous work exist that would be enough to support decision-making.

If this is not the case, straightforward, LCT-based criteria may be derived and used. Straightforward criteria often can be derived from the available experience and knowledge gained from previous successful applications of LCT to comparable waste

management contexts. The waste hierarchy can be seen as a first point of reference to derive such straightforward, LCT-based criteria. However, often more specific evaluations are necessary, also to be able to establish the environmental preference amongst specific options belonging to the same level of the waste hierarchy. Developing and using straightforward criteria can thus be seen as a valuable step in between applying the waste hierarchy and conducting a new LCA. Straightforward criteria should be based on scientifically sound methodologies and data that are accepted by relevant stakeholders. These can be for example criteria derived from detailed LCAs based on a consistent framework methodology, like the International Reference Life Cycle Data System (ILCD) Handbook⁵⁶ and the ISO 14040 series⁵⁷.

In addition to straightforward criteria, LCT-based software tools for the environmental assessment of waste management systems and strategies may be used. These need to be based on quality-assured data and might take into account straightforward criteria.

LCT-based software tools should allow users to carry out an LCA in a quick and simple manner. If intended for non-LCA experts they must focus on the most relevant technical and management parameters only, not requiring LCA expertise, and helping the user up to results interpretation, identifying its limits. To develop software that provides a useful output and is practical to use, a thorough understanding of the intended user and business requirements is necessary. Depending on the user, the software may be used to quantify environmental impacts across the life cycle of a particular waste stream or an entire integrated waste management system.

The software needs to be designed and developed for a given by-product group or waste, focusing on the key issues or criteria to be considered and building on relevant experience/studies/data sets. Non-specific, simplified tools attempting to cover waste in general will not provide sufficiently robust results and these tools should not be used to support important waste management decisions. The software should also have a user-friendly interface, allowing users to vary default technical and management parameters according to their specific situation.

When straightforward criteria do not apply, then conducting a new LCA may become needed to identify the preferable waste management option. These aspects are presented on the next sub-chapters.

As the decision-tree shows, not only the environmental aspects should be considered to provide comprehensive support to decision making and policy making. The LCA results should, therefore, be complemented with information gained from analyses of the social and economical implications.

The more general “Technical guide to Life Cycle Thinking and Assessment in waste management for waste experts and LCA practitioners” provides detailed guidance on all of these aspects.

The next chapters of this guide provide guidance on how to select the best overall environmental option for bio-waste management using a life-cycle approach.

⁵⁶ <http://lct.jrc.ec.europa.eu/assessment/projects>

⁵⁷ http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_tc_browse.htm?commid=54854

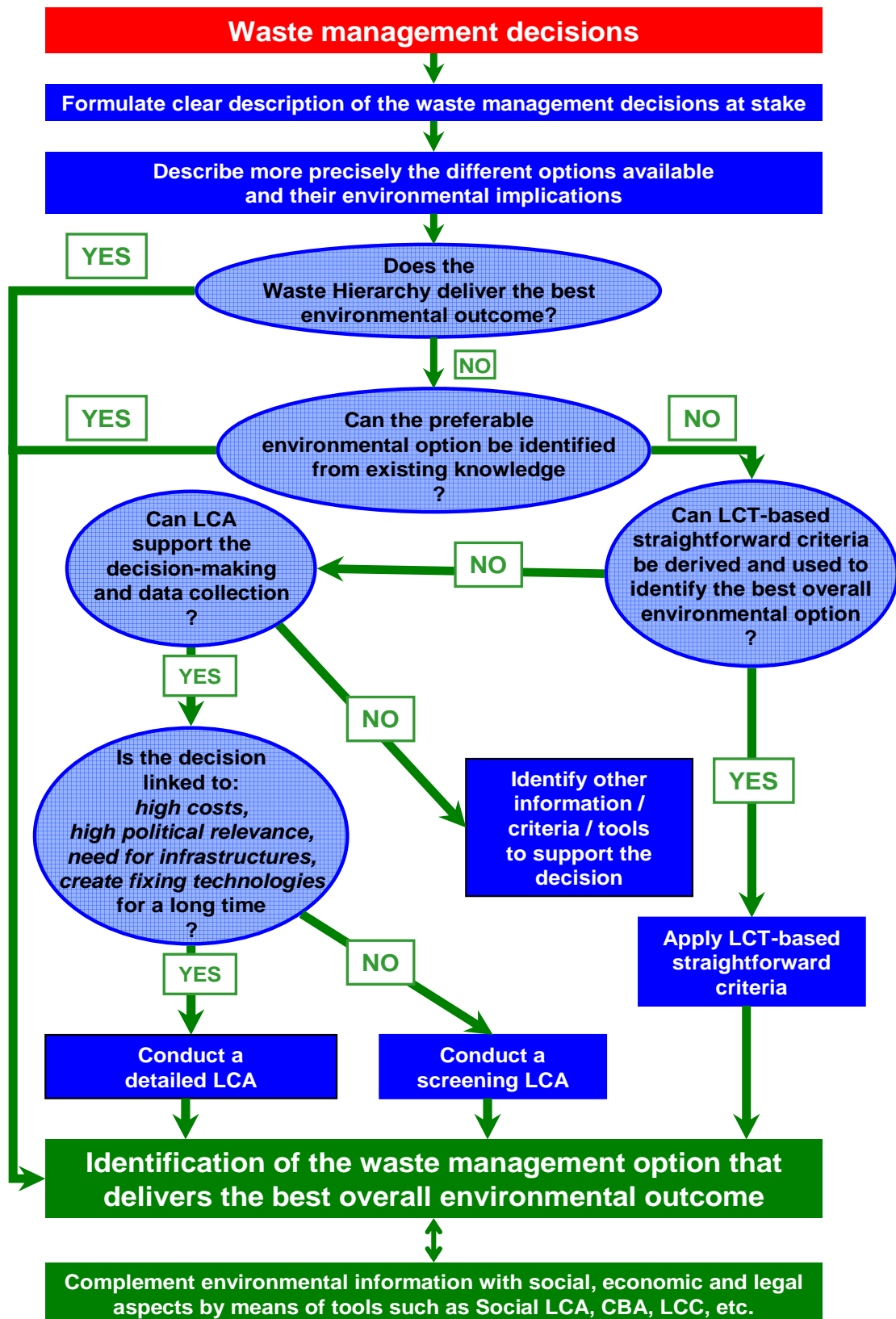


Figure 5: How to approach waste management issues and decision with a LCT-based approach

3.2 General guidance

3.2.1 Overview and key principles

The following provides some general guidance and will help to ask the relevant questions in the right context before decisions are taken pre-maturely. Any figures provided for making “yes-no” decisions should be used with the necessary caution. These figures may not cover all relevant cases but can be taken as an indication.

Figure 6 gives an overview of the guidance tree to support sound environmental decisions for the bio-waste management.

Any decision making process should consider the following aspects of the waste management context under study:

Table 5: Aspects to be considered in bio-waste decision making

Criteria	Type of influence
bio-waste quantity (tonnes/year)	determining the economic feasibility and sometimes technical feasibility
bio-waste quality (C/N, biodegradability, moisture, etc.)	determining the technical feasibility
availability of treatment facilities	determining the economic feasibility
energy demand/supply (efficiency of valorisation and replaced energy production process)	influencing the benefits of energy recovery
needs in term of agronomy and soil quality and related outlet market for compost/digestate (although it may be assumed that the market always exists if it is adequately stimulated)	influencing the environmental and economic benefits of using compost in soil
chemical equilibrium through time of bio-waste	determining the technical feasibility of anaerobic digestion and composting
bio-waste contamination	determining the technical feasibility of anaerobic digestion and composting (in fact the feasibility of using compost from those processes)

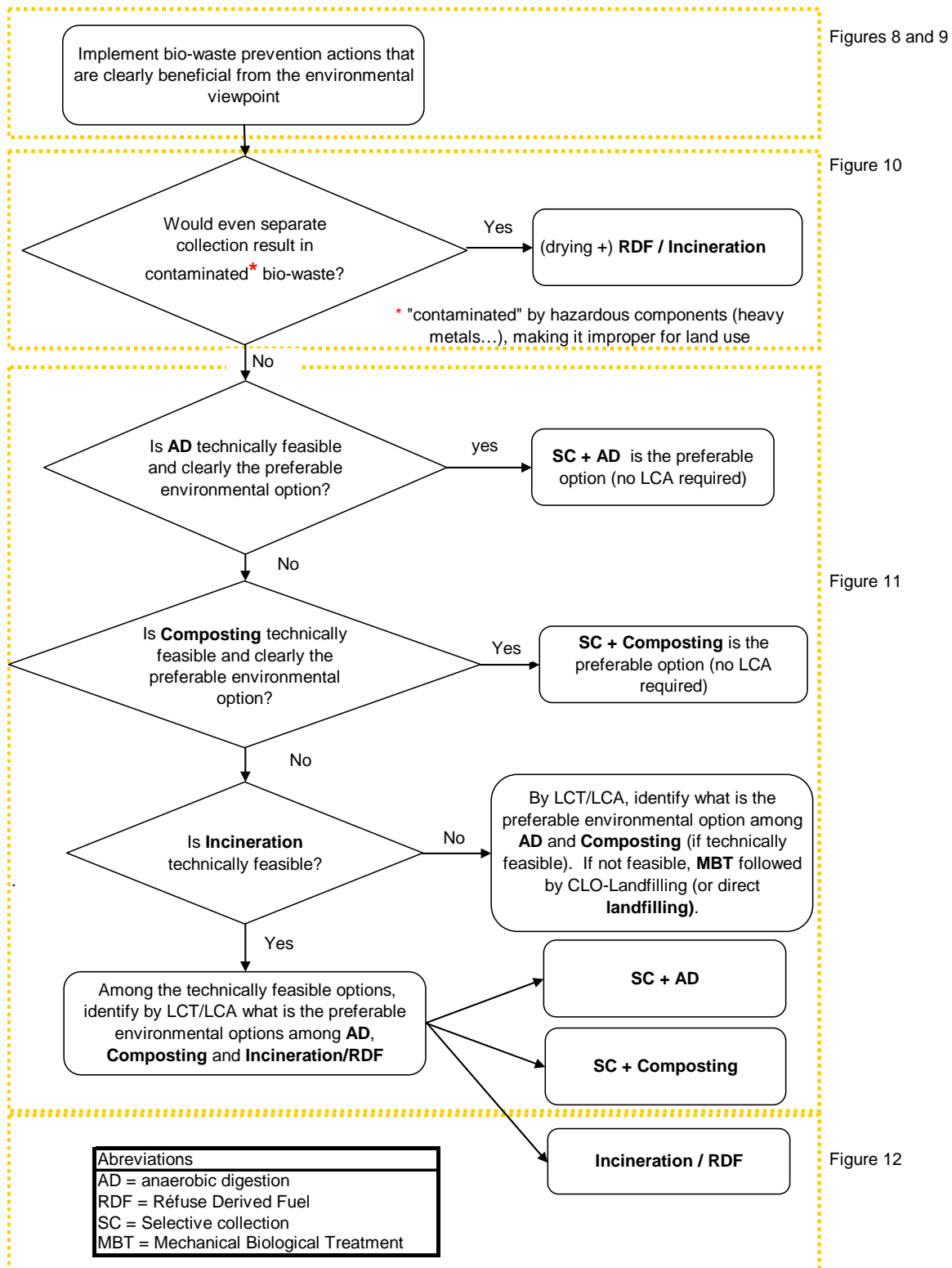


Figure 6: Overview of the guidance tree to support sound environmental decisions for the bio-waste management.

The general guidance provided by Figure 6 reads as follows:

- 1) Optimising prevention (apply it when it is beneficial for the environment, i.e., mainly by avoiding food losses and bio-waste contamination);
- 2) If bio-waste is contaminated (this should rarely be the case for a stream of selectively collected bio-waste, except for specific streams such as medical waste), it should be incinerated as such or as RDF, possibly after drying;
- 3) If Anaerobic Digestion (AD) is feasible⁵⁸ (depending, among other things, on the amount of waste and its composition; e.g., composting only food waste without any woody material will be extremely difficult) and the conditions are favourable to AD (see below), then selective *collection + AD* (including composting of digestate) is likely to be the preferable environmental option. The rationale is to combine both producing valuable compost (allowing more efficient and less impacting agriculture) and efficient energy recovery.

Favourable conditions include:

- a. Compost is needed as soil improver (it may be assumed that the market always exists if it is adequately stimulated);
 - b. Compost obtained from direct composting and from composting of digestate are similar in composition and quantity (there is no scientific consensus on this point; some authors consider less compost is obtained from composting of digestate than from direct composting);
 - c. Energy recovery from biogas displaces energy production that is largely based on fossil fuels (coal, oil, gas);
 - d. The AD process is well managed (e.g., no methane emissions).
- 4) If composting is feasible but AD is not, and if the conditions are favourable for composting (see below), then *selective collection + composting* is likely to be the environmentally preferable option. The rationale is to produce valuable compost (allowing more efficient and less impacting agriculture). Favourable conditions include:

- a. Compost is needed as soil improver (it may be assumed that the market always exists if it is adequately stimulated);
- b. Any type of energy recovery (alternative options are incineration, as such or as RDF, after drying or not) would not displace energy production that is largely based on fossil fuels (coal, oil, gas);
- c. The composting process is well managed (e.g., no methane emissions);

⁵⁸ For the purpose of this document, a treatment option is considered "feasible" when technically possible

- 5) If neither AD, nor direct composting are feasible⁵⁹, but incineration is feasible, incineration (or producing RDF) is likely to be the environmentally preferable option. Drying of the bio-waste may be necessary for efficient energy recovery; for thermally treated mixed waste, drying is not necessary. However, drying might be advantageous from an environmental viewpoint when heat at low temperature is available while this heat would be lost if not used for drying).

Incineration is to be made in a plant treating diverse waste streams together (no source separated collection is needed). Therefore, the bio-waste stream cannot be regarded independently from the other streams. The guidance tree therefore considers the existing facilities for the overall mixed waste.

- 6) If AD, direct composting, and incineration are unfeasible, then no (marked) environmental benefit can be drawn from bio-waste treatment. Therefore, bio-waste should be treated together with other waste streams (no source separated collection).

In order to minimise fugitive gas emissions from landfills (methane), incineration (with low or no energy recovery) or MBT (with composting or AD, but without valorisation of the compost) are preferable to direct landfilling. However, landfilling remains a legal option as long as the requirements established by the Landfill Directive (99/31/EC)⁶⁰ are met.

Also landfills have undergone tremendous technological improvement in the last couple of decades, making them less damaging for the environment. Leachate in modern landfill is collected and treated, and the landfill gas produced is recovered and frequently utilised for energy generation. These measures have significantly improved the environmental performance of waste landfilling compared to old, poorly managed landfills⁶¹. In case the target set by the Landfill Directive (less than 35 % of total municipal waste produced in 1995 should be put into landfill in 2016) cannot be achieved, it is absolutely necessary to have a treatment process (incineration or MBT).

- 7) In the other cases (i.e., when at least 2 processes among AD, direct composting and incineration are feasible), LCA is needed to determine which option is the most favourable for the environment. Each system has specific advantages:

⁵⁹ This may happen when composting is too costly and/or compost cannot be valorised in agriculture (if contaminated or if there is no demand in an economically accessible area). However, this last case should rarely occur in the EU

⁶⁰ Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste states

⁶¹ Manfredi, S. & Christensen, T.H. (2009): Environmental assessment of solid waste landfilling technologies by means of LCA-modeling. *Waste Management* 29, 32-43

- Incineration might be the most efficient option with respect to energy recovery. Incineration becomes particularly "competitive" when the displaced energy production generates quite large environmental pressures (particularly coal-based power production, which is CO₂-intensive);
 - Direct composting might be the most efficient option in improving soil quality (through input of nutrients and organic matter). There is much debate about whether compost from direct composting has a better quality or is produced in a larger amount than compost from digestate. In specific circumstances, and if the compost from direct composting has a significantly higher quality than the composted digestate, the advantages of a better soil quality may outweigh benefits from energy recovery, mainly in case the displaced energy production generates rather small pressures on the environment (e.g., hydropower);
 - If compost from direct composting is similar to compost from digestate (both composition and quantity) and if the energy recovery is efficient, AD (+ composting of digestate) in principle allows for combining both benefits from direct composting and energy recovery.
- 8) In the case of AD or incineration, energy recovery should be optimised: high energy efficiency, permanent, ongoing energy consumer (e.g., avoid seasonal applications such as district heating) no or very small losses, displacing fossil fuel-derived energy with associated high environmental pressures.

Detailed justification regarding these criteria for managing bio-waste is presented in the paragraphs below.

3.2.2 Prevention of bio-waste

The decision-tree on bio-waste prevention (Figure 8) starts the global guidance tree. It shows the main relevant actions as a function of the type of waste (source).

3.2.2.1 Prevention of food waste

Obviously, avoiding food losses is a key issue. As it avoids all lifecycle stages, i.e., production, transformation, distribution and storage, use (cooking) and end-of-life, there are major benefits.

According to a study conducted for the European Commission in 2010⁶², the estimated food waste generation in EU-Members States is equal to approximately

⁶² Bio Intelligence Service (2010) (in association with AEA Energy & Environment and Umweltbundesamt): Preparatory study on food waste across EU 27, interim report for European Commission DG-Environment

175 kg/capita/year (~84 millions tons/year). The contributions from different sources to this overall amount are presented in Figure 7.

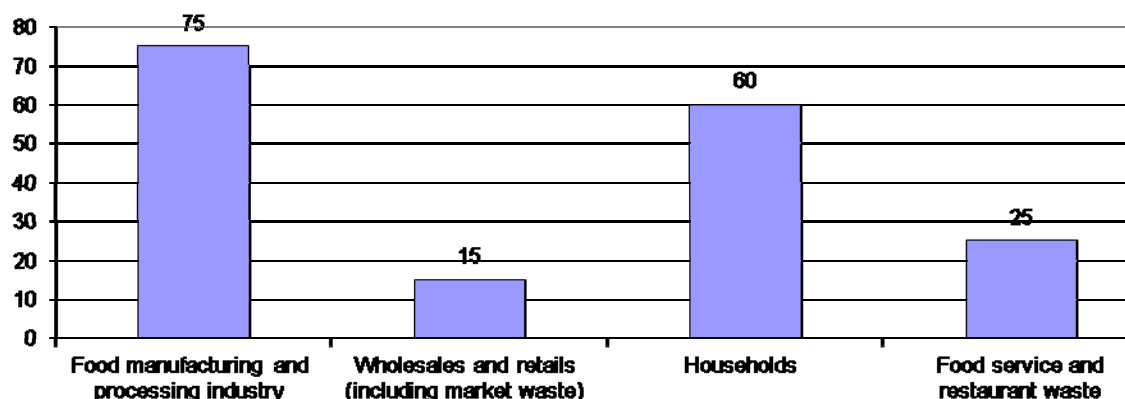


Figure 7: Estimated food waste generation (kg/capita/year) in the EU27⁶³

An Austrian study⁶⁴ differentiates food waste found in household waste by:

Table 6: Example of food waste differentiation in Austria

	kg/capita/year
Food in unopened original packaging	4.5
Food in opened original packaging	4.5
Food leftovers	3.1
Preparation residues	5.6

From the table it can be seen that, overall, about 18 kg/capita/year of food waste represents are differentiated in Austria. This is equal to about 13% of the overall residual household waste (~60 kg, as from Figure 7).

The new waste management plan of the Brussels Region (May 2010) states that 12% of households residual waste is made of food in unopened and opened original packaging. This represents 15 kg of food waste/capita/year.

The Commission communication COM(2010)235⁶⁵ underlines that: *“In case of ambitious prevention policies, up to 44 million tonnes CO₂-equivalent could be avoided (mainly from avoided emission related to food production and transport)”*.

⁶³ Bio Intelligence Service (2010) (in association with AEA Energy & Environment and Umweltbundesamt): Preparatory study on food waste across EU 27, interim report for European Commission DG-Environment

⁶⁴ Obersteiner, G, Schneider, F (2006) "NÖ Restmüllanalyse 2005/06", BOKU, Vienna

⁶⁵ Communication from the commission to the council and the European parliament on future steps in bio-waste management in the European Union (COM(2010)235))

Changing the type of food bought (e.g., buying fresh, unpacked, unprepared food to select the right amount of food instead of packed, possibly pre-cooked food might be regarded as a prevention action, but the environmental benefits are questionable):

- Environmental benefits arise from lower wastage through buying optimal quantity and from less packaging;
- Environmental losses arise from less efficient cooking (industrial cooking benefits from large scale), possibly more losses (packaging protects the food), possibly better valorisation of industrial organic waste (e.g., chicken skin and bones are valorised as materials with specific characteristics by the food industry, while they become household waste to be treated as a mix of bio-waste).

The balance between benefits and losses can be checked either using LCA results from the literature or performing specific LCA. This type of LCA is more demanding than an LCA on just the management of the bio-waste, as it concerns the full product lifecycle.

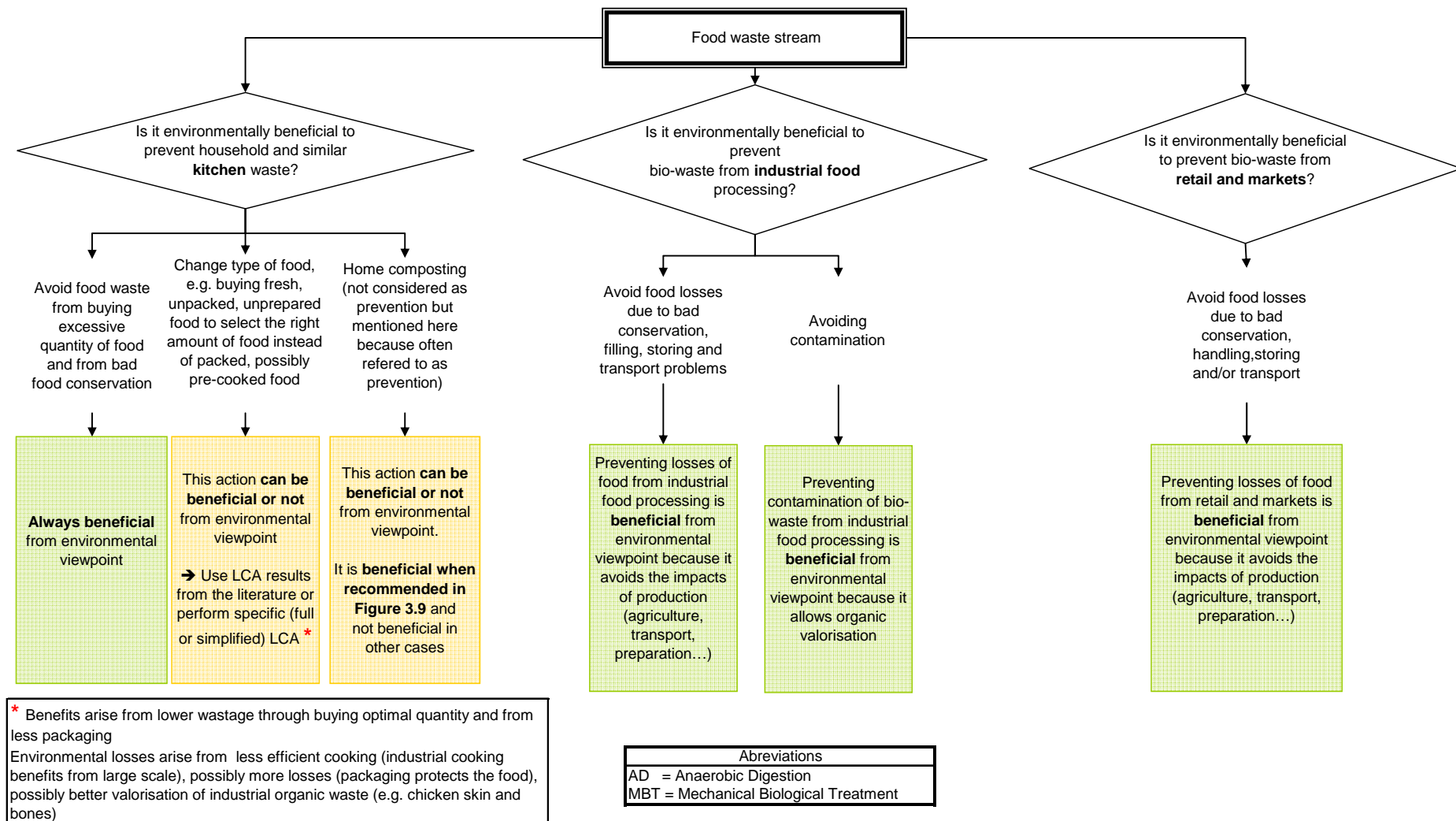


Figure 8: Guidance tree to support sound environmental decisions for the bio-waste management: Relevance of prevention – food waste

3.2.2.2 Prevention of park and garden waste

To prevent green waste from park and gardens means, for instance, selecting plants that grow slowly in order to lower the amount of maintenance waste or to apply grass mulching when cutting grass.

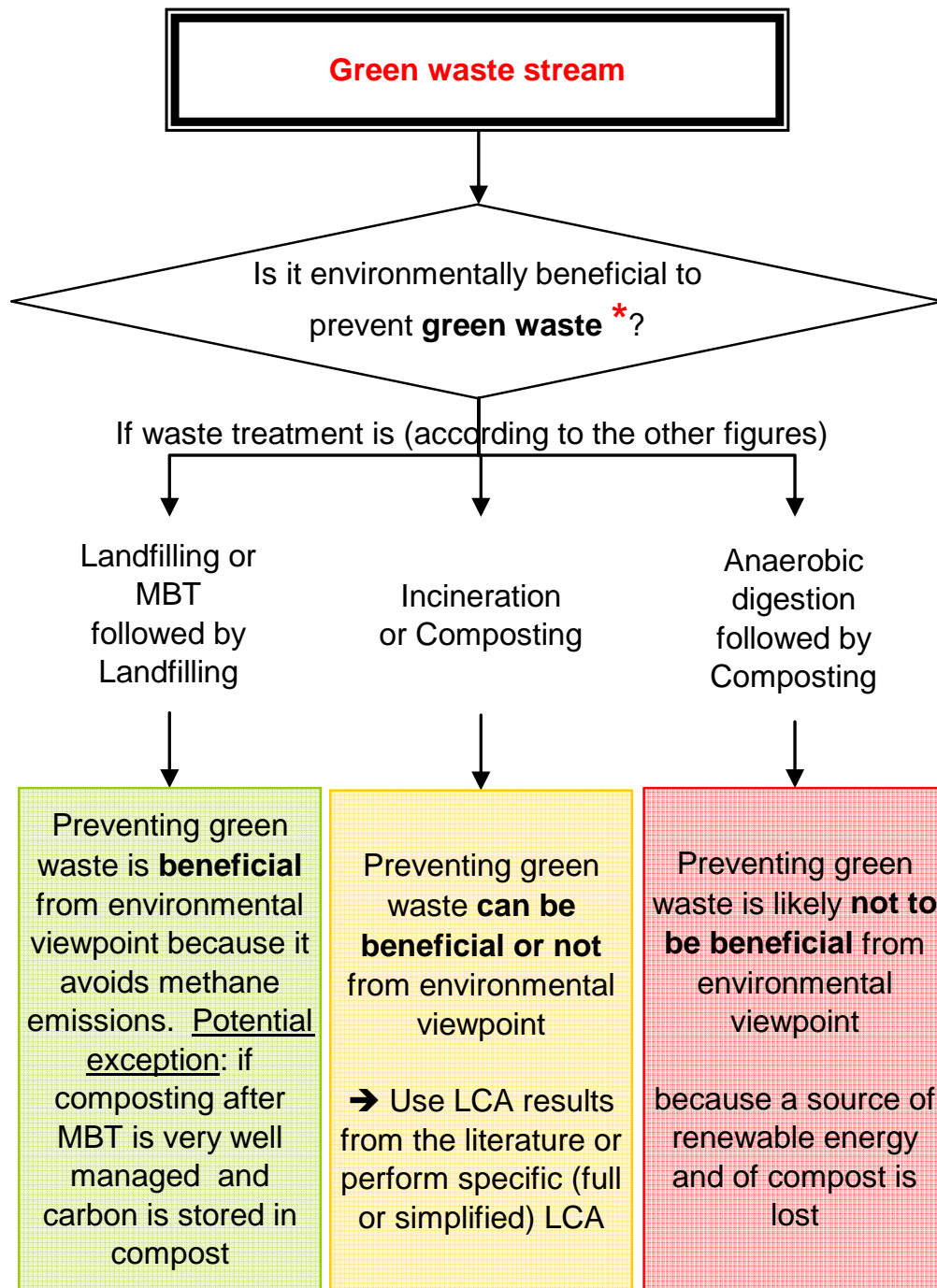
Production of park and garden waste does not always have adverse effects on the environment. Hence, prevention of green waste is not always beneficial to the environment.

If bio-waste management includes energy production and compost production, it may be environmentally beneficial to produce and manage green waste (production captures CO₂ and this CO₂ is largely emitted back during end-of-life).

If there are limited benefits (incineration with lower energy recovery), it should be assessed (by LCA) whether these benefits compensate or not the impacts of collection and handling.

When there are virtually no benefits (e.g. when the bio-waste would be landfilled, or sent to MBT), prevention is likely to be more favourable. Although there might be some methane production and carbon storage, possible methane losses are likely to make the environmental balance unfavourable.

If compost is not valorised (though this should not be a frequent case for quality compost) and there are significant adverse environmental consequences from selective collection, prevention might also be preferable to composting.



* to prevent green waste means selecting plants that grow slowly and grass mulching in order to lower the amount of maintenance waste

Figure 9: Guidance tree to support sound environmental decisions for the bio-waste management: Relevance of prevention – green waste

3.2.3 Management of contaminated bio-waste

3.2.3.1 Key principles

In some cases⁶⁶ bio-waste can be contaminated by pollutants that are not eliminated by biological treatments (AD or composting). Those pollutants can be pathogens and micro-pollutants (e.g., dioxins) from animal waste, but also pesticides and fungicides from vegetable waste from the food industry. If biological treatment was applied to contaminated bio-waste, the pollutants may be transferred to the digestate/compost and, indirectly, to the food chain. This risk is unacceptable. For this reason, the Animal By-Products Regulation⁶⁷ (Commission Regulation (EC) N° 1432/2007, amending EC Regulation 1774/2002) prohibits application of organic fertilizer or soil improvers other than manure to pastureland. The use on other types of lands of, for instance, digestate or compost is allowed only if the digestate/compost has been treated with a specific decontamination method. The best solution, whenever possible, is to avoid contamination upstream, using preventive measures. If not, a thermal treatment is necessary.

In order to optimise the energy balance, bio-waste should first be dried if it has elevated moisture content (for thermally treated mixed waste, drying is not required from a technical viewpoint) and then sent to a plant with high energy recovery efficiency.

The preference between “drying or not drying” should be established either by LCT (existing LCT-based evidence, straightforward criteria, etc.) or by performing a new (full or simplified) LCA, though it largely depends on whether the bio-waste will be used to produce RDF or will be incinerated. Drying is often applied when the bio-waste is transformed and used as RDF.

If the acceptance criteria for the RDF-burning process (e.g., chlorine content, heavy metal content, etc.) are not met, classic incineration is the remaining option, possibly with high energy recovery efficiency. When modelling the benefits of incineration, LCA authors should check whether using RDF replaces a conventional (fossil) fuel or another waste stream that needs to be treated elsewhere. In this last case, RDF incineration causes an additional treatment of another waste stream.

⁶⁶ Normally bio-waste collected selectively is not contaminated.

⁶⁷ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:320:0013:0017:EN:PDF>

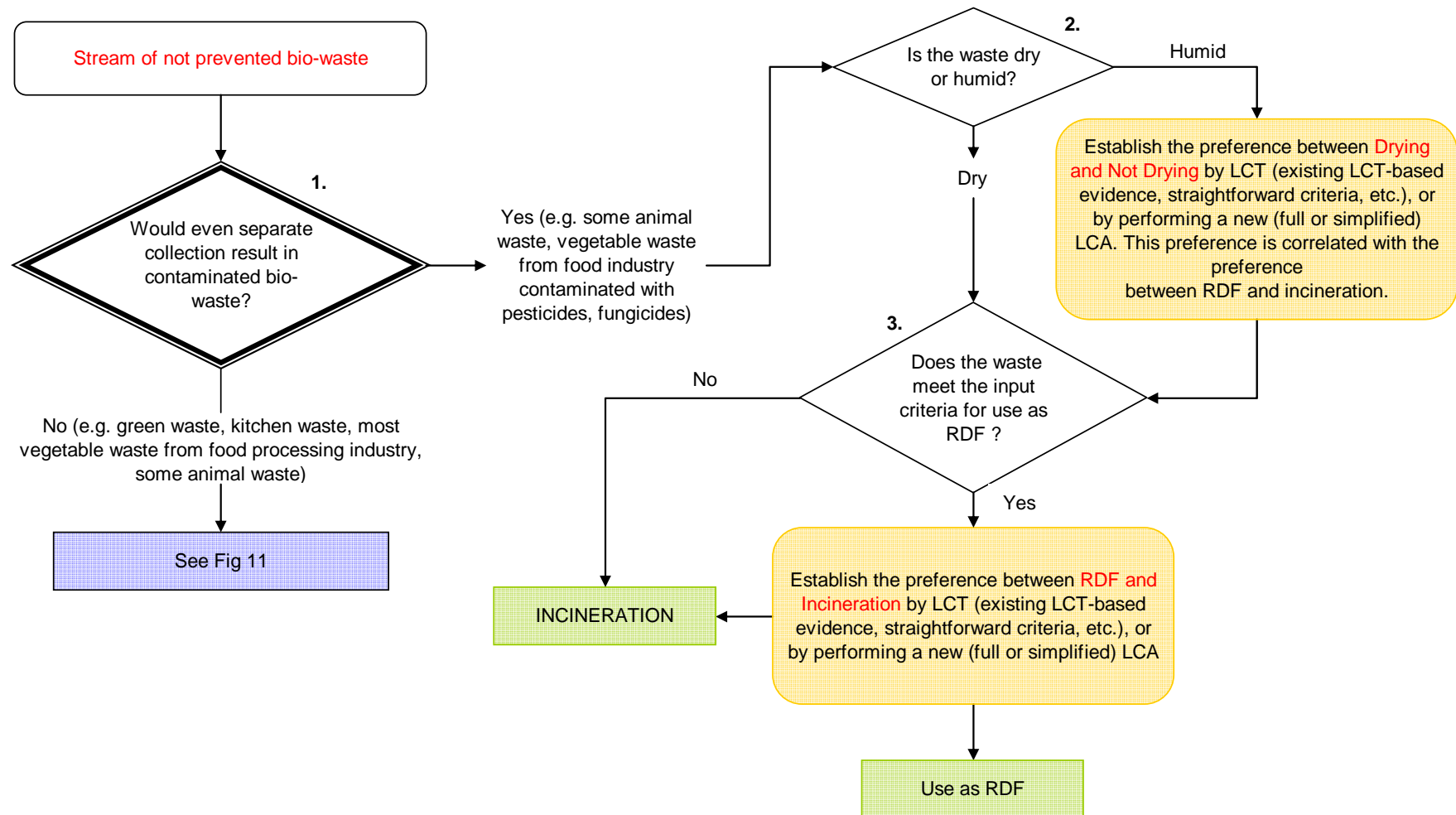


Figure 10: Guidance tree to support sound environmental decisions for the bio-waste management: contaminated bio-waste

3.2.3.2 Discussion related to key decision criteria

The following paragraphs give some explanations about the questions presented in Figure 10.

1. Would separate collection result in contamination of bio-waste?

Bio-waste can be polluted by organic micro-pollutants (dioxins, pathogens, and pesticides), inorganic micro-pollutants (heavy metals) and/or large inorganic pollutants (metals fragments, packaging).

In the latter case (large inorganic pollutants), foreign objects should be partially removed by a mechanical treatment. Upon treatment, AD and composting remain feasible processes.

Removal of heavy metals from the compost is not practical. If these are present in the bio-waste stream, they will also generally be present in the compost.

For contamination by micro-pollutants, a specific analysis is needed. Some micro-pollutants are destroyed at the AD temperature (function of duration and pH value). In this case, temperature control requires extra care from operators, but in principle, anaerobic digestion and composting remain feasible processes. If the micro-pollutants are not destroyed at the temperature of anaerobic digestion/composting (e.g., dioxins), then a thermal treatment is necessary.

2. Is the waste dry or humid?

Mainly due to high water content, the net calorific value (on wet weight) of food waste from households is very low (generally about⁶⁸ 2-4 MJ/kg, depending on the moisture, compared to about 9 MJ/kg⁶⁹ for MSW and 45 MJ/kg for oil). Therefore, incineration of bio-waste generates little energy. Drying bio-waste increases the net calorific value up to about⁷⁰ 12-18 MJ/kg. This maybe beneficial for the environment if the drying process consumes less energy than the supplemental energy derived from using dried bio-waste instead of humid bio-waste. This is typically the case when low-temperature heat is available and this heat would otherwise not be used. Separation and drying equipment must be installed and their corresponding impacts must be included in the environmental assessment.

For thermally treated mixed waste, drying is not required from a technical viewpoint. Therefore, for relatively small amounts (< 3 – 5 000 t/year, higher amount is acceptable in large size plants), direct incineration is an acceptable option, saving separate collection. The availability of an energy source at low temperature (e.g., from large combustion or power plants) should be considered as an opportunity to dry the waste at low price and with a clear environmental advantage.

⁶⁸ Warrington (NHWAP survey, 1994) (quoted in Thermal methods of municipal waste treatment, Biffa Ward 2003): 4.17 MJ/kg (31.6% moisture)

⁶⁹ ADEME (2009) National Campaign to characterise French household waste ("Campagne nationale de caractérisation des ordures ménagères ")

⁷⁰ ADEME (2009) National Campaign to characterise French household waste ("Campagne nationale de caractérisation des ordures ménagères ")

3. Does the waste meet the acceptance criteria for use as RDF?

RDF users cannot accept all types of contaminants in RDF. RDF may be used as fuel for:

- Cement kiln;
- Incinerator;
- Lime-burning kiln;
- Coal-fired power plants;
- Paper industry (boiler);
- Wood industry (wood fire drier);
- Steel industry;
- Glass industry.

Pollutants that are destroyed at burning temperature do not generally represent a problem. For other pollutants, it depends on the process. For example, cement kilns cannot accept more than 1% chlorine as it would cause the so-called "cycling-effect" (chlorine accumulates up to corrosion concentrations because it evaporates at high temperature and condenses again in the kiln at lower temperature). Lime producers have requirements specific to their own users.

There are European Standards for Solid Recovered Fuels (SRF) prepared by the European Committee for Standardization (CEN)⁷¹. In particular, reference shall be made to the CEN/TC 343⁷².

The table below gives the key properties of RDF that need to be considered by a potential user in cement kiln when appraising its relative attractiveness.

Table 7: Technical specification for the use of RDF in cement kiln ⁷³

Minimum net calorific value required	Main burner: 15-20 MJ/kg Precalciner: 10-16 MJ/kg
Maximum water content	12-15% (mass)
Chlorine content	0.5-1% (mass)
Particle size	< 30 mm
Biomass content	40-60% (mass)
Heavy metal content	4-200 ppm/dry product, depending on the specific heavy metal considered (see details below*)
Sulphur content	0.5-1% (mass)

* The RAL standard of the German association for quality (Guetegemeinschaft Sekundärbrennstoffe und Recyclinbholz e.V, about 80 members, many preparing RDF) provides some limits:

⁷¹ <http://www.cen.eu/cen/Pages/default.aspx>

⁷² <http://www.cen.eu/CEN/Sectors/TechnicalCommitteesWorkshops/CENTechnicalCommittees/Pages/Standards.aspx?param=407430&title=CEN/TC+343>

⁷³ Christian Delavelle (AJI-Europe) (2009). State-of-art of the use of nonhazardous waste in cement plants. Study performed for ADEME (French Environment Agency) + comments from " Rudolf Müller, Bavarian Environment Agency and Dr. Siegfried Kreibe, bifa Environmental Institute" on min LHV.

Table 8: Limits values for chemicals in RDF from RAL

Element	RDF from <u>household</u> waste (ppm on dry basis)	RDF from <u>production</u> waste (ppm on dry basis)
Cd	4	4
Hg	0.6	0.6
Tl	1	1
As	5	5
Co	6	6
Ni	25	80
Se	3	3
Te	3	3
Sb	25	25
Pb	70	190
Cr	40	125
Cu	200	400
Mn	50	250
V	10	10
Sn	30	30
Be	0.5	0.5

The RAL Standard also quotes some values applied by French cement producers:

Hg < 10 ppm

Cu < 300-500 ppm

Pb < 500 ppm

Zn < 500 ppm

Cr < 300 ppm

Cd + Tl + Hg: < 100 ppm

As + Co + Ni + Se + Te + Sb + Cr + Sn + Pb + V: < 2500 to 10 000 ppm

Mn + Cu + As + Co + Ni + Sb + Cr + Pb + V + Cd + Tl + Hg: < 10 000 ppm

Treating the waste requires addressing every fraction. When comparing the use of RDF in cement kiln with alternative options, the full picture must be considered. As pollutant concentrations are generally lower in RDF, the fraction from which the RDF is produced contains increased pollutant concentration. The effects of this concentration increase should be considered because the mass balance must be the same for all options.

3.2.4 Management of non-contaminated bio-waste

3.2.4.1 Key principles

Bio-waste is a source of material and energy. Selecting the preferable environmental option for bio-waste management corresponds to selecting the option that allows the highest exploitation of those two characteristics. This statement is highlighted in an inventory of existing studies applying LCT to bio-waste management (2008)⁷⁴: *“As the environmental benefits of the avoided products are often greater than the negative environmental impact of the collection and treatment of bio-waste, it is recommended to optimise treatment and collection based on the selection of the most interesting option for recycling or energy recovery from bio-waste.”*

As Anaerobic Digestion (AD) (including composting of digestate) allows combining both benefits, it is likely to be the preferable environmental option in many instances. However, in some cases, the advantages of producing energy are so high that the benefits of optimising energy production through going to an efficient (co-)incineration plant might exceed the lost benefits of material valorisation, at least for some environmental pressure indicators. When this is suspected, an LCA should be performed to produce a comprehensive environmental assessment. Energy recovery in (co-)incineration of bio-waste (dry matter < 25%) can be lower than from AD⁷⁵. Therefore, for wet bio-waste the advantages of incineration can only arise from the saved emissions (not from saving the energy resource).

Another key question is whether “AD + composting of digestate” produces a similar amount of compost as “direct composting” and whether the composition of the compost-output from the two processes is similar. This is a key question when comparing AD to direct composting. If the composition is similar and the amount generated is similar, then “AD + composting of digestate” is likely to be environmentally preferable to direct composting.

When anaerobic digestion is not technically feasible, but composting is technically feasible, the choice is mainly between:

- Composting (recycling nutrients and humus);
- Incineration (energy production).

In this case, a LCA is necessary to balance both types of benefits. Key parameters include process efficiency, waste composition, transportation distances, type of bins for source separated collection, characteristics of the electricity mix replaced. Conducting this type of LCA may not lead to robust conclusions because the current LCA methodologies do not satisfactorily account for the environmental benefits arising from use of compost on land.

⁷⁴ Bart Krutwagen, Jaap Kortman and Koen Verbist (2008). Inventory of existing studies applying life cycle thinking to bio-waste management. Study performed for Joint Research Centre (JRC), Institute for Environment and Sustainability (IES)

⁷⁵ See e.g., Wellinger et al., 2006: Energieproduktion aus Küchenabfällen, Biomasse Schweiz

When material valorisation (composting or anaerobic digestion) is not technically feasible, then the bio-waste should be co-incinerated with high energy recovery efficiency. This can happen through:

- Extraction from mixed waste (MBT) and (drying) RDF production;
- Direct incineration of bio-waste together with other types of waste.

Very often the selection of the bio-waste treatment option needs to be made considering the whole municipal solid waste stream and not specifically the bio-waste stream.

The straightforward LCT-based criteria for managing non-contaminated bio-waste are presented in Figure 11 and the subsequent sub-chapters.

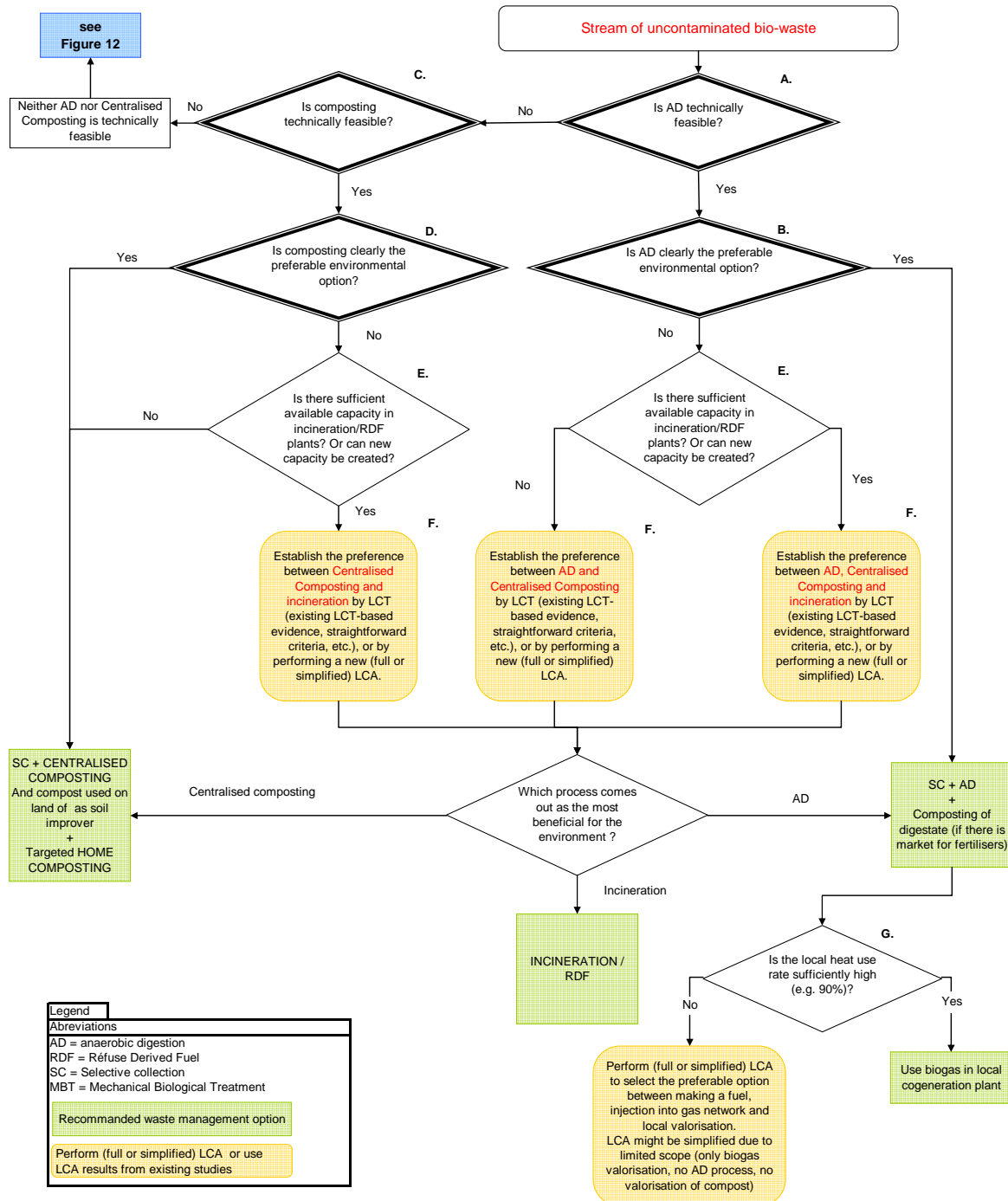


Figure 11: Guidance tree to support sound environmental decisions for the bio-waste management: non-contaminated bio-waste (part I/II)

3.2.4.2 Discussion related to key decision criteria

The following paragraphs give some explanations about the questions presented in Figure 11. The issue on decentralized composting (i.e. home composting) is further discussed in a separate paragraph.

A. Is AD feasible (from technical viewpoint)?

The following two questions are seen as crucial to establish whether establishing the anaerobic digestion process is technically feasible:

I. **Is there enough organic material to stabilize the anaerobic digestion process?**

Anaerobic digestion requires a minimum amount of bio-waste material for the process to be technically feasible (to stabilise temperature, moisture). Depending on local conditions and the type (origin) of bio-waste, this minimum amount ranges 1000 to 5000 tonnes/year⁷⁶. If co-digestion (with agricultural wastes or sewage sludge) is applied, there is no lower weight limit.

II. **Does the waste composition allow anaerobic digestion (ammonia concentration, biodegradability, etc.)?**

Some key technical criteria for anaerobic digestion plants are related to the substrate:

a. Degradable carbon concentration;

Dalemo (1996)⁷⁷ underlines that: *“the slowly degradable organics (lignin) is not degraded in the digester and also diminishes the ability of the micro-organisms to degrade moderately carbohydrates (cellulose and hemi-cellulose) in the cells walls.”*

Table 9: Degradation of organic substances⁷⁸

	Maximum degradation (%)	Proportion of methane in the produced biogas(%)
Organics, slows (lignin)	negligible	50%
Carbohydrate, rapid	100	50%
Protein	80	69%

⁷⁶ This should be considered as a purely indicative value

⁷⁷ M. Dalemo (1996) “The modeling of an anaerobic digestion plant and a sewage plant in the Orware simulation model”. Swedish University of Agricultural Sciences, Department of Agricultural Engineering, Swedish Institute of Agricultural Engineering.

⁷⁸ Adapted from M. Dalemo (1996) “The modeling of an anaerobic digestion plant and a sewage plant in the Orware simulation model”. Swedish University of Agricultural Sciences, Department of Agricultural Engineering, Swedish Institute of Agricultural Engineering.

Fat	95	78%
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- b. Ammonia concentration; *"Ammonia has been known for many years as a potent inhibitor of methanogenesis. A number of publications seem to indicate that the free ammonia form (NH_3) rather than ammonium (NH_4^+) is the real inhibitor (e.g., Kroeker et al., 1979⁷⁹). This means that the pH and temperature (via pH-value) have a strong effect on the inhibitory concentration by influencing the equilibrium."*⁸⁰;
- c. C/N ratio⁸¹ (for composting the digestate) because it determines the proper functioning of microbiology. In practice, the C/N ratio of the incoming waste in the digester must be greater than or equal to approximately 15-20. In addition to low production of biogas, a C/N ratio lower than 15-20 leads to very high loads of nitrogen that can cause problems during processing. Conversely, an efficient microbiology also requires that the incoming waste contains a minimum of nitrogen. Therefore, it is not possible to treat only oils and fats that contain almost no nitrogen. Low-nitrogen streams should be mixed with waste with high nitrogen content before treatment. The operator can combine different streams in order to reach an adequate average C/N ratio.

Table 10 shows C/N ratios of different biodegradable waste streams.

⁷⁹ Kroeker, E.J.; Schulte, D.D.; Sparling, A.B. and Lapp H.M. (1979). Anaerobic treatment process stability. Journal of the Water Pollution Control Federation 51 (4): 718-727.

⁸⁰ " Process design of agricultural digesters ", Arthur Wellinger, Nova Energie GmbH, 1999

⁸¹ Carbon content divided by nitrogen content (weight ratio)

Table 10: C/N ratio of different types of waste⁸²

	Maximum degradation
Leaves	40-80
Paper	125-180
Fruit wastes	20-50
Garden wastes	5-55
Food wastes	14-16
Vegetable wastes	11-19
Grass clippings	9-25
Slaughterhouse wastes	2-4

So, if the waste composition is suitable (enough kitchen waste) and if there is sufficient amount⁸³ of bio-waste, *anaerobic digestion + composting of digestate* can be considered technically feasible.

B. Is AD clearly the preferable environmental option?

AD is clearly the preferable environmental option when 5 conditions are met:

- I. Compost is needed for soil improvement;
- II. Compost obtained from direct composting and from composting of digestate are similar in composition and quantity;
- III. There is a user for the net produced electricity and/or thermal energy;
- IV. Energy recovery from biogas displaces an energy production that largely uses fossil fuels (coal, oil, gas);
- V. The AD process is well managed (no methane emissions).

Those conditions are discussed in more details in the following paragraphs.

I. Is there a sufficient outlet for compost used for soil improvement?

It should be considered that the market always exist if adequately stimulated (promotion, quality control to give guarantee of composition, information of farmers, adequate legislation, etc.).

So, if there is a sufficient market for compost and digestate as soil improver, composting and anaerobic digestion fulfil the condition.

⁸² <http://www.norganics.com/applications/cnratio.pdf>

⁸³ or there is available treatment capacity; in this case, there is no minimum amount required and the specific waste composition may be a less crucial factor.

For other uses of compost (growing media, landscaping industry, sports grounds, vineyards, orchard, hobby gardening etc.), the preferable management option is not clear because of lack of sufficient (evidence from) literature.

II. Are compost obtained from direct composting and from composting of digestate similar in composition and quantity?

A key parameter to select the environmental preference between bio-waste management systems is the type of compost utilization. Krutwagen et al. (2008)⁸⁴ underline that: *"The environmental benefits of compost differ strongly and are not always clear in LCAs. If compost is used as top over of landfill sites, the positive impact is usually low."*

Compost utilization is mainly determined by compost standards applicable in different countries in Europe. Currently, there is great variability amongst the EU states, as underlined in the annex of the COM(2010)235⁸⁵: *"The compost market of the EU shows a huge variety in terms of quality parameters, assessment criteria and quality assurance systems. Compost quality refers to the overall state of the compost with regard to physical, chemical and biological characteristics. [...] Within the EU, the limit values adopted by the Member states vary widely, with the north being generally more stringent than the south. A recent study has recently evaluated the quality profile of compost products in Greece, and examined their compliance with the Greek standards. They also examined how the compost complied with more stringent limit values valid in other countries of the EU [...] The scientists measured the physical and chemical parameters (moisture, organic matter, electrical conductivity, pH and heavy metals), stability indicators (self-heating potential), and biological parameters (microbial population, pathogen indicators and selected pathogens) to determine the quality of the compost products. The results showed that there were wide variations in the quality of the study products, even within the same group of products"*.

The same communication from the Commission, also lists the most important parameters that could limit the compost utilization: *"the most important parameters from the point of view of environment protection standards, public health and the soil are those related to pathogens, inorganic and organic potentially toxic compounds (heavy metals, phthalates, and polycyclic aromatic hydrocarbons) and stability."*

The quality and the utilization of compost vary according to the treatment process and input materials. A key issue is compost-like biologically stabilised materials from MBT (which in this document is referred to as compost-like

⁸⁴ Bart Krutwagen, Jaap Kortman and Koen Verbist (2008). Inventory of existing studies applying life cycle thinking to bio-waste management. Study performed for the Joint Research Centre (JRC), Institute for Environment and Sustainability (IES)

⁸⁵ Communication from the commission to the council and the European parliament on future steps in bio-waste management in the European Union (COM(2010)235))

output, “CLO”). Farrell & Jones (2009)⁸⁶ state that: *“It is clear that volumes of MSW composts are likely to increase in many countries and that we urgently need sustainable ways for their disposal.”*

However, compost-like biologically stabilised material from MBT has low quality and should therefore not be used as soil improver:

Caroline Saintmard (2005)⁸⁷: *“Various studies have shown that end-products from MBT have 5 to 10 times more heavy metals content compared to compost resulting from source separated bio-waste. [...] Therefore, it seems that these treatment methods should remain regulated according to legislation relating to landfilling, and that the application of stabilised biodegradable wastes should be restricted to limited applications (non-agricultural use).”*

In case compost made from non-selective collection had a sufficient quality, its recovery on soils should be allowed. It all depends on the quality of the output, the type of stream and treatment followed, and the characteristic of the soil on which the compost will be applied. Given a control of the use of such output (through a certificate of use) and an adequate level of traceability and depending on the fulfilment of relevant compost quality criteria, the compost from non-selective collection should be used as far as possible and appropriate.

Farrell & Jones (2009)⁸⁸ highlight that: *“Mechanical biological treatment (MBT) of mixed waste streams is becoming increasingly popular as a method for treating municipal solid waste (MSW). Whilst this process can separate many recyclates from mixed waste, the resultant organic residue can contain high levels of heavy metals and physical and bio-logical contaminants [...] From a legal viewpoint in many countries, composts derived from MSW remain wastes (rather than compost), even after successful processing to remove pathogenic microbes and organic matter stabilization. This can be due to the risk from heavy metals and organic pollutants alongside the physical risks from sharps, glass shards, and the aesthetical problem of plastic scraps that remain highly visible even after composting. This legal barrier prevents the wholesale application of MSW composts to agricultural/horticultural land (potentially the largest market for composts), despite strong evidence of increases in soil and crop quality after application [...] In contrast, MSW composts have the potential to play an extremely beneficial role in the remediation and regeneration of a variety of contaminated and post-industrial sites.”*

The authors conclude that although MSW-derived composts are of low value, they still represent a valuable resource, particularly for use in brownfields.

⁸⁶ M. Farrell and D.L. Jones. (2009). *Critical evaluation of municipal solid waste composting and potential compost markets*. Bioresour. Technol. In press.

⁸⁷ Caroline Saintmard (2005). *“Managing Biodegradable Household Waste: What prospects for European Local Authorities?”*. Study performed for ACR+

⁸⁸ M. Farrell and D.L. Jones. (2009). *Critical evaluation of municipal solid waste composting and potential compost markets*. Bioresour. Technol. In press.

These authors emphasize the need for proper investigation of the contaminants levels of compost-like biologically stabilised materials from MBT and associated full risk assessment for use on the target land area (e.g., contaminated and post-industrial sites).

III. Is there a user for the net produced power and/or thermal energy from AD?

Sonesson et al (2000)⁸⁹ state that: *“anaerobic digestion⁹⁰ results in the lowest environmental impact of all the solid waste management systems [...] Composting gives environmental advantages compared to incineration methods.”*

However, the authors highlight that this environmental conclusion might change if energy from incineration displaces coal for power (heat) production because the environmental benefits of incineration in terms of climate change become higher. Energy recovery should be highly efficient. In that case incineration can be seen similar to anaerobic digestion with respect to several pressure indicators (or even better depending on the energy efficiency of using biogas). However, other aspects such as CO₂ fixation in soil or peatland preservation remain more favourable in the AD option.

Trine Lund Hansen (2005)⁹¹ states that: *“composting and anaerobic digestion of municipal organic waste have similar environmental effects regarding agricultural application of the residues. However, the lack of energy production from composting and the risk of emissions from the process (especially open windrow composting) generally make this technology less attractive than anaerobic digestion from an environmental point of view”*. Based on this, anaerobic digestion appears to be intrinsically a better option than composting. However *“Increased soil quality due to addition of organic matter is not included in the module, since it has not been possible to quantify the impacts of this (Hansen et al., 2004⁹²)”*. This limits the reliability of the conclusions. The conclusions might be different if those benefits were taken into account, as there is no consensus on the similar environmental effects regarding agricultural application of both types of compost.

The European Compost Network states that N₂O and CH₄ emissions in storage and application differ due to the often low C/N ratio and the high ammonium concentration in digestion residues. The long term effect on soil biodiversity, soil and plant health, soil physical properties is not sufficiently known in the case of digestate⁹³.

⁸⁹ Sonesson et al (2000). *Environmental and economic analysis of management systems for biodegradable waste*. Resources, Conservation and Recycling 28 (2000) 29-53.

⁹⁰ Biogas used as fuel for busses (replaces diesel); Sludge from AD is spread on arable land. Only N and P input was considered (no benefit from bringing organic matter).

⁹¹ "Quantification of environmental effects from anaerobic treatment of source-sorted organic household waste", Ph. D Thesis Trine Lund Hansen, September 2005, Institute of Environment and Resources, Technical University of Denmark

⁹² Status for LCA i Danmark 2003, Introduktion til det danske LCA metode- og Konsensusprojekt. Draft, Danish EPA, Copenhagen, Denmark

⁹³ European Compost Network (ECN). Comment made for the invited expert consultation of the draft of this document

It should be noted that some current studies are analysing uncontrolled methane emission:

- From storage lagoons;
- From digestate;
- From the initial composting phase if the digestate is composted; and
- During and after application of liquid or semi-solid digestion residues.

IV. Does energy recovery from biogas displace an energy production that is largely based on fossil fuels (coal, oil, gas)?

If so, then the environmental advantages of AD (especially in terms of avoided emissions of greenhouse gases) are likely to be very high. If, instead, energy recovery displaces hydropower or another source of (renewable) energy with small environmental pressures, the benefits of those savings are also rather small. In this case, direct composting can compete environmentally with AD and no a-priori preference can be established.

V. Is the AD process well-managed (no methane emissions)?

There are potentially considerable gas emissions (e.g. methane, ammoniac, laughing gas) from AD, which should be minimised as much as possible.

However modern plants are assumed to be well-managed. If the question concerns a new plant, decision makers should consider a well-managed plant with very small (negligible) atmospheric emissions.

C. Is direct composting feasible (from a technical viewpoint)?

Direct composting is easier to operate than AD and, therefore, is generally feasible for non-contaminated bio-waste. However, to establish whether or not direct composting is technically feasible the following aspects should be considered:

I. Is there enough organic material to justify the investment?

Although it is feasible to operate relatively small plants, there is a scale effect and a minimum amount of bio-waste is needed to be economically feasible. Depending on local conditions and the type (origin) of bio-waste, this minimum amount ranges from 500 to 1000 t/year⁹⁴. This type of economic limitation should be assessed by LCT-based reasoning.

If co-composting (with agricultural wastes or sewage sludge) is applied there, is no lower weight limit.

II. Does the waste composition allow direct composting (C/N, biodegradability, etc.)?

⁹⁴ This should be considered as a purely indicative value

The composting process requires a balanced input of both types of organic materials: ligneous (to provide structure to facilitate aeration) and non-ligneous (to provide heat during rapid degradation).

D. Is direct composting clearly the preferable environmental option?

Direct composting is clearly the preferable environmental option when 3 conditions are met:

I. Compost is needed for soil;

II. Energy recovery from biogas would not displace an energy production using from fossil fuel (coal, oil, gas);

III. Direct composting process is well managed (no methane emissions).

Conditions I and III are the same as for AD.

Condition II: If energy recovery would displace hydropower or another source of (renewable) energy with small environmental pressures, the benefits of those savings would also be rather small. In this case, direct composting is likely to be better than incineration or RDF production from an environmental point of view.

E. Is there sufficient available capacity in incineration/RDF plants? Or can new capacity be created?

Generally, the decision to build an incineration plant is not linked to the presence of the organic fraction in the mixed waste. Therefore, the existence of an incineration plant might be regarded as an external parameter for the bio-waste management policy.

F. How to perform a LCA to determine the environmentally preferable option?

Many parameters influence the environmental preference among composting, anaerobic digestion and incineration of bio-waste. However, as mentioned in many studies, the most important aspects are typically the type of substituted energy (for AD and incineration) and the specific use of compost.

When incineration produces power (and/or heat), saving a highly impacting production process (e.g., energy from a coal-fired plant), the environmental preference between composting or anaerobic digestion and incineration should be determined by LCA. The positive effects of bringing organic matter to the soil should be included in the evaluation. There should also be specific consideration for the efficiency of the end-use of the energy recovered from anaerobic digestion.

G. Is the local heat use rate (close to) 100%?

As already mentioned in the document, biogas can be used:

- For heating;
- In combined heat and power (CHP) units;
- As a fuel for vehicles. This application requires the same type of engine as those used for natural gas. However, the biogas will have to be upgraded: the methane content needs to be increased to 95% and the gas should then be compressed;
- As upgraded biogas injected into the gas grid.

All of these options have potential advantages as they all save a similar amount of other energy sources.

If biogas can be used locally with high efficiency (cogeneration and integral use of the produced heat), it can be convenient to use it locally because it avoids compression and transport. However, the key element is the energy mix replaced. For instance, in case the locally generated energy replaces nuclear/renewable energy mixes, a delocalised use replacing fossil energy would probably offer greater environmental benefits.

The key point here is the "integral use", meaning heat is used to avoid producing heat using fossil fuels all year long and 100% of what is produced.

The following decision tree (Figure 12) addresses those situations where neither anaerobic digestion nor composting of bio-waste is technically feasible.

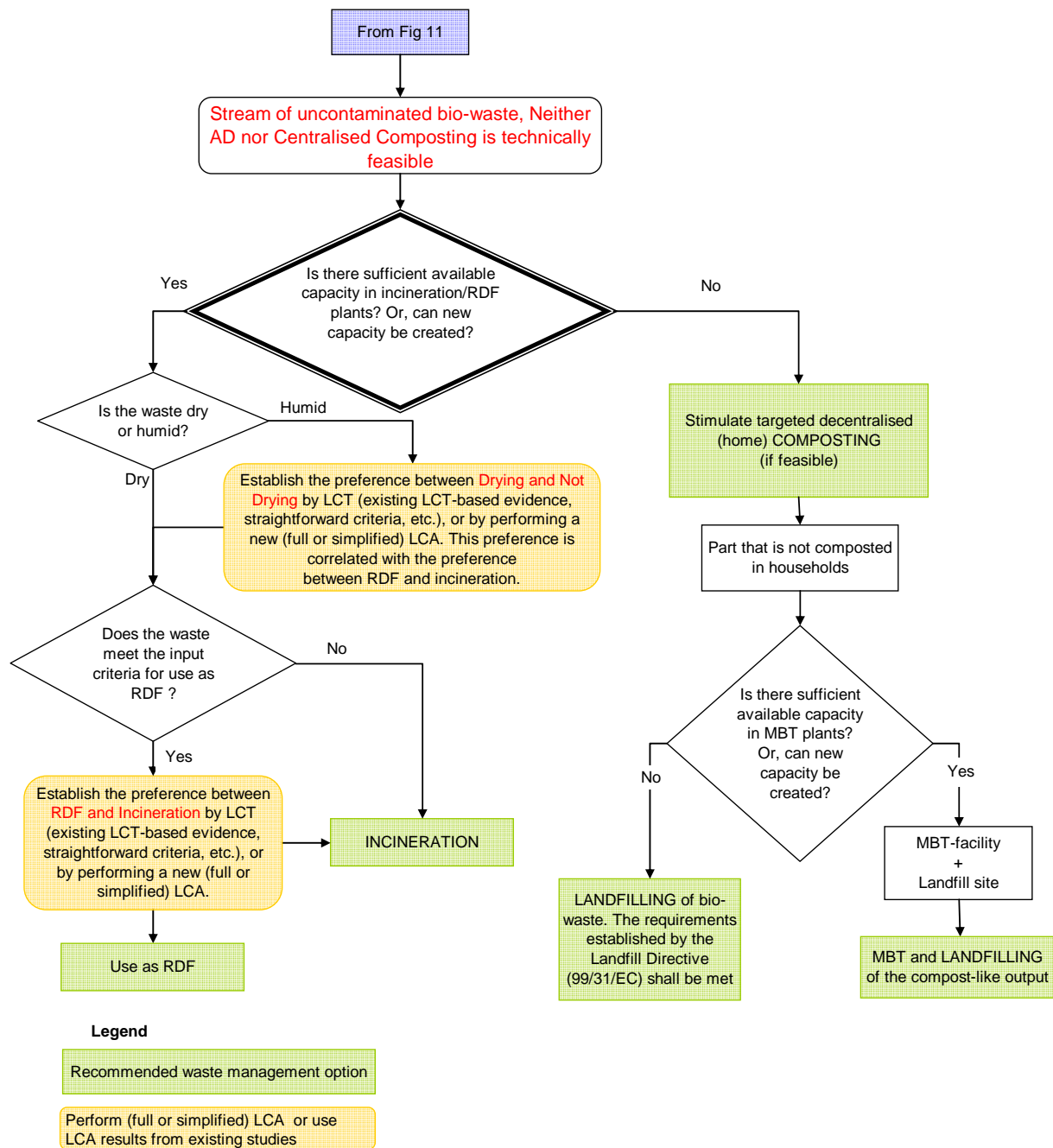


Figure 12: Guidance tree to support sound environmental decisions for the bio-waste management: non-contaminated bio-waste (part II/II)

1. Is there sufficient available capacity in incineration/RDF plants? Or can new capacity be created?

See 3.2.3.2, point E "Is there sufficient available capacity in incineration/RDF plants? Or can new capacity be created?"

2. Is the waste dry or humid?

See 3.2.3.2, point 2 "Is the waste dry or humid?"

3. Does the waste meet the input criteria for use as RDF?

See 3.2.3.2, point 3 "Does the waste meet the acceptance criteria for use as RDF?"

4. MBT and landfilling?

Existence of treatment infrastructures may influence the selection of the bio-waste management option, mainly from the economic point of view (rather than from an environmental point of view).

Although separate collection of bio-waste has been successfully implemented in Europe, if the bio-waste cannot be treated by anaerobic digestion or composting, it should be treated together with the rest of municipal solid waste (MSW). Therefore, very often the choice needs to be made considering the whole municipal solid waste stream and not specifically the bio-waste stream. The possible treatments for MSW are:

- Landfilling;
- Extraction of some fractions from mixed waste (MBT) for both RDF production (it may require drying) and either simple stabilisation (to avoid further methane production in landfill) or possibly AD (but without valorisation of the compost).

Boldrin et al. (2011)⁹⁵ underline that the advantage of the production of RDF and subsequent co-combustion in coal power plants or combustion in dedicated RDF incinerators is that RDF has higher energy content than wet waste, making it suitable for incineration technologies with higher efficiency for electricity production. However, a drawback of this solution is the substantial energy requirement for the production of RDF, affecting the level of energy recovery from waste.

RDF should be less attractive to users than other fuels for a mix of technical, economic, legal and regulatory reasons but it offers the advantage of saving the use of alternative combustible material (mainly fossil fuels) and, among others, the related CO₂ emissions.

⁹⁵Boldrin, A., Andersen, J.K., Christensen, T.H. (2011) Environmental assessment of garden waste management in the Municipality of Aarhus, Denmark. Waste Management 31, 1560-1569

Treating the waste requires addressing every fraction. Therefore, when comparing the use of RDF in cement kiln with alternative options, the full picture must be accounted for. As pollutants concentration is generally lower in RDF, separating an RDF fraction from the residual waste increases the pollutants concentration in the remaining fraction. The mass balance must be the same for all options. This must be considered in the modelling.

The Landfill Directive (99/31/EC) must also be considered. It dictates a progressive reduction of landfilling of biodegradable waste (article 5 states: "*not later than 15 years (i.e., 2016) after the date laid down in Article 18(1), biodegradable municipal waste going to landfills must be reduced to 35 % of the total amount (by weight) of biodegradable municipal waste*"). As a consequence, the biodegradable waste diverted from landfills shall find different treatment routes (e.g., AD, composting, incineration). Alternatively, the share of biodegradable waste in the mixed MSW must be reduced (to meet the target set by the Landfill Directive) prior to landfilling. A possible treatment preceding landfilling is the so-called mechanical biological treatment (MBT), where MSW is separated into different fractions using mechanical and magnetic mechanisms. Biological treatment typically follows, a composting step (or, seldom, by AD). Overall, MBT results in a marked reduction of the waste organic content. As a result, waste's potential for gas generation in landfills is markedly reduced and so are odour problems.

5. Discussion related to home composting

Andersen et al. (2010)⁹⁶, as well as other studies in Europe, state that: "*There is in general a lack of reliable environmental assessments with consistent data, which is also emphasized by the studies by Weidema et al. (2006), and Lundie and Peters (2005).*"

So, when analysing the environmental consequences of home composting, several aspects should be investigated:

- What proportion of the population participates in home composting?
 - What proportion of the composters conducts composting in accordance with recommended conditions (waste diversity, regular mixing, moisture control, etc.)?
 - What are the emissions and potential effects on health if not performed as required?

Andersen et al. (2011)⁹⁷ state that: "Home composting is considered to be a horticultural recreational activity [...] It is difficult to describe home composting as one single standard technology

⁹⁶ Andersen, J.K., Boldrin, A., Christensen, T.H., Scheutz, C. (2010). Home composting as an alternative treatment option for organic household waste: an environmental comparison using LCA-modelling. Submitted to Waste Management.

⁹⁷ Andersen, J.K., Boldrin, A., Christensen, T.H., Scheutz, C. (2011). Mass balances and life-cycle inventory of home composting of organic household waste. Waste Management 31, 1934-1942.

because the waste producer is also the processor and end-user of the compost (Jasim and Smith, 2003). The composting process is taking place in many different ways and with very different operational schemes, which is one of the reasons for the lack of scientific studies in this field [...] Thus, there has until now been a lack of full LCIs for single-family home composting."

- How will compost be used? To what extent is it beneficial (compared to industrial compost used on fields)? Does it replace compost, peat, use of fertilizers? Home compost is likely to be too rich to use as a growing media substitute by householders and is much more likely to be used as a soil conditioner in gardens. Does it allow reducing the use of pesticides?

Andersen et al. (2010)⁹⁸ states that: "The primary benefit of composting is that the compost can be used on land as a fertiliser or as a conditioner to enhance soil structure, thereby reducing the reliance on industrial fertilisers and/or peat [...] *It was clear from the surveys that the estimated substitutions of peat, fertiliser and manure were far from 100%. Many compost users were not aware of the arguments for using compost instead of peat, fertiliser and manure in the garden, and therefore did not change the use of these products when applying compost. [...] Thus, the estimated total substitution was around 50%, which means that there is potential for improvement.*"

Home composting (HC) avoids waste collection and produces compost. As it may not capture the full bio-waste stream from households, there is always a co-existing bio-waste treatment process.

- If the alternative is "AD + composting of digestate", the benefits of HC from saving collection are rather small compared to the benefits from energy recovery through AD.
- If the alternative is "centralised composting " due to HC benefits from saving collection, HC is preferable if:
 - the process is well-managed (low emissions, but there is a lack of data and evidence on this topic), and
 - compost is used in a way that fully exploits its benefits (humus and nutrient inputs), as when used on field.

If the first condition is not fulfilled, the decision-maker has to balance, based on LCA/LCT, the benefits of saving collection vs. emissions from HC.

If the second condition is not fulfilled, the benefits of saving collection are rather small compared to the benefits from using compost.

⁹⁸ Andersen, J.K., Christensen, T.H., Scheutz, C. (2010) Substitution of peat, fertiliser and manure by compost in hobby gardening: User surveys and case studies. Waste Management 30, 2483–2489.

- If the alternative is "incineration with mixed waste ", the decision maker has to balance, based on LCA/LCT, the benefits of saving collection + using compost at home vs. impacts of incineration, including energy recovery.
- If the alternative is "landfilling", HC is clearly the preferable option if well-managed (otherwise, decision-makers should consider risks for human health due to specific emissions).

In any case, encouraging home composting should be focussed on areas for which a favourable environmental balance can be assumed (well-managed process and use with benefits from the organic content of compost

4 Further recommendations on how to perform full or simplified LCA

The following paragraphs give some explanations about the boxes in Figure 11 and Figure 12 that recommend conducting an LCA for non-contaminates biowaste. It is important to bear in mind that results from an LCA cannot usually be generalized, but are case-specific. This does not preclude using existing LCA evidence as a starting point for a wider LCT-based evaluation, but only within the scope of these existing LCAs and carefully considering the limitations of their transferability.

4.1 General simplification rules

There is no official definition of a simplified LCA. In fact, all LCAs must be complete according to ISO 14040 series on LCA. However, some simplifications are necessary in practice and are allowed when they do not affect the results significantly and especially not the conclusions and recommendations. Indeed, in many cases,

1. LCA results depend mainly on a limited number of data and technical or management parameters (other parameters can often be disregarded, as they do not significantly influence the results)
2. Parts of the lifecycle are common to all compared options
3. Results are similar for different environmental pressure indicators.

To be able to simplify the system model and analysis in this sense, one must first know the above issues, i.e. this simplification needs to work with initial estimates and reasonably best and worst case scenarios to evaluate the possibility for simplification and identify where more focus is to be put. This will build on original data but also on existing studies and insights, that are however always limited to a range of analysed product systems, such as e.g. certain bio-waste management options, not on LCA in general.

In those cases, performing an LCA can be simplified, or better focused, by:

1. Looking for quality data only and for data with relevant influence on the results. This means that using secondary data and default values is acceptable for:
 - most (non-key) processes of the background system;
 - many (non-key) processes also in the foreground system;
 - non-key data of key processes;
 - non-key parameters.

2. Excluding processes that are common to all compared options
3. Limiting the analysis to the relevant environmental pressure indicators.

This allows both cost saving and time saving while still yielding reliable and robust results. Any resulting limitation (e.g., limited applicability to specific cases and conditions where the parts that were left out matter) must however be highlighted in the results and explicitly be considered in the conclusions and recommendations.

4.2 Discussion on possible simplifications

Some simplifications are possible when performing an LCA. The following general management issues can for instance be considered; for these, it will be evaluated where and how simplifications are possible for these issues:

1. What is the environmentally preferable option for biogas use?
2. Which is the environmentally preferable option between incineration and MBT?
3. Which is the environmentally preferable option between incineration and SC+AD?

4.2.1 What is the environmentally preferable option for biogas use?

The environmental benefit of producing biogas originates from its high (55-60%) methane content, making it suitable as a substitute for an alternative combustible. The different options to use biogas are:

- Burning locally to produce electricity. Power can be used locally and/or delivered to the network. The efficiency is generally moderate (36-38%⁹⁹), significantly lower than (very) large power plants using natural gas (up to 55-60% for combined cycles);

⁹⁹ The range varies between 26% and 42% according to the thermal efficiency. (Techniques de production d'électricité à partir de biogaz et de gaz de synthèse Auteurs: C. COUTURIER - Date: January 2009 – Study for: RECORD 07-0226/1A)

- Burning locally as a substitute for a permanent user of natural gas for heating purposes. The "permanent" character is crucial as biogas is produced continuously. If the demand is discontinuous (heating stopped during the summer, at night, on week-ends...), the heat generated will be wasted (flared). Biogas storage can help avoid biogas wastage, but this is only feasible for limited periods of non-consumption (i.e., several hours up to 3 days); thus, it is not feasible for seasonal (e.g., summer) storage. Biogas storage also requires increased investment and involves higher operating costs. If demand is not continuous and permanent, power production might be preferable;
- Injecting into the natural gas network or liquefying and transport. In those cases, it functions as a substitute for natural gas. Biogas is not a 1/1 replacement for natural gas (it is 1/1 for the methane part but as it also contains CO₂ for about 50%, replacement is about 1/2). It must be upgraded to methane (CO₂ removal) and then polished with propane to meet technical specification;
- Using as fuel for vehicle¹⁰⁰. This application requires the same type of engine as those used for natural gas. However, the biogas will have to be upgraded: the methane content needs to be increased to 95% and the gas needs then to be compressed. Biogas can be used either as a substitute for natural gas (no additional car driven by natural gas) or as a substitute for gasoline or diesel (additional cars driven by natural gas). The different types of substitution should be analysed in sensitivity analysis.

For any of those uses, the efficiency of energy production should be set high, as it markedly influences the environmental performance.

The following simplifications could be made when conducting the LCA:

- Bio-waste collection and biogas production may be disregarded since they are common to all options¹⁰¹;

¹⁰⁰ Reference: see e.g. " *Life Cycle Assessment of Biofuels in Sweden*", Pål Börjesson, Linda Tufvesson & Mikael Lantz, Lund University, May 2010,
http://www.miljo.lth.se/svenska/internt/publikationer_internt/pdf-filer/Rapport%2070.pdf

¹⁰¹ Any partial model in this sense limits other analytical options, e.g. to quantify the absolute amount of benefit and impact and to show relative gains by introducing a biogas beneficiation system. Importantly, as the biogas production is excluded, this simplification cannot be used to compare biogas use with other biowaste management options, of course.

- This LCA should be focussed on determining and modelling the actual substitution. Ultimately, the amount of natural gas (or other combustible or electricity) saved is the key criteria. If the replaced (“avoided”) alternative energy source is a specific local one, the saved life cycle impacts or of their production is the benefit, if the produced biogas or electricity is fed into the national grid, the mix of replaced grid gas or grid-electricity is the benefit. I.e. the saved amount of the actually replaced source is the direct benefit of this biogas use: to quantify this benefit, the alternative system needs to be modelled (or national grid-mix LCI data should be used).

4.2.2 What is the environmentally preferable option between incineration and MBT?

Bart Krutwagen et al. (2008)¹⁰² state: *“The variations in the LCT results are largely dependent on local factors such as the availability of recycling and energy recovery options, the avoided products and the efficiency of treatment facilities.”*

In this case, the LCA aimed at selecting the best environmental option may be simplified as follows:

- Bio-waste collection (mixed with other waste) may be disregarded since it is common to both options. However, transport to the treatment facilities may need to be included if the transport distances and/or the means of transport differ significantly;
- The inventory for the sorting process itself may be approximated since it is relatively small compared to the potential benefits of the valorisation of obtained sub-streams;
- The study should include all concerned waste types as they are treated together; however, differences might be very small for metals. Recovery of metals may thus be left out of the assessment, as the recovery rate is similar for both options.

A second key issue for simplification is the lower calorific value of the biowaste: a too low value (due to excessive high water content) will prohibit incineration with energy recovery (while biogas production is still an option).

MBT technologies are quite recent and as noted in ACR+ (2005)¹⁰³, various studies show that compost-like output (CLO) from MBT has a heavy metals content 5 to 10 times higher than compost from source separated bio-waste; this precludes its use on land as fertiliser / soil improver.

¹⁰² Bart Krutwagen, Jaap Kortman and Koen Verbist (2008). Inventory of existing studies applying life cycle thinking to bio-waste management. Study performed for Joint Research Centre (JRC), Institute for Environment and Sustainability (IES)

¹⁰³ Caroline Saintmard (2005). *“Managing Biodegradable Household Waste: What prospects for European Local Authorities?”*. Study performed for ACR+

At the same time, is the energy of the biowaste lost, hence the option to generate useful energetic products is lost.

However, according to Farrell et al. (2009)¹⁰⁴ *“Mechanical biological treatment (MBT) of mixed waste streams is becoming increasingly popular as a method for treating municipal solid waste (MSW). Whilst this process can separate many recyclates from mixed waste, the resultant organic residue can contain high levels of heavy metals and physical and bio-logical contaminants. [...] Critical evaluation reveals that the best option for using this organic resource is in land remediation and restoration schemes. For example, application of MSW-derived composts at acidic heavy metal contaminated sites has ameliorated soil pollution with minimal risk. This study concludes that although MSW-derived composts are of low value, they still represent a valuable resource particularly for use in post-industrial environments”*¹⁰⁵.

Especially in such situations of complex trade-offs a more detailed, while focussed LCA is the only way to determine the favourable option, unless available LCAs of similar scope and sufficient quality allow to transfer their conclusions to the analysed case.

4.2.3 What is the environmentally preferable option between incineration and SC+AD?

The environmental pressures and benefits by generated products of anaerobic treatment are mainly affected by site specific conditions, such as climate, methane emissions (function of the type of emissions treatment), soil type and agricultural practice for the applied treated waste as well as substituted energy source.

In this case, the LCA aiming at selecting the best environmental option may be simplified. However, the following aspects should be considered:

- The substituted energy sources (due to power/heat production from burning waste / biogas) are a crucial aspect. Key parameters are: amount of energy substituted, permanence of the demand (for heat) and type of energy source displaced (coal, gas, nuclear, renewable...). If the displaced energy production is known, it should be used; if not, sensitivity analysis should be used, addressing gas, coal and mix grid;
- If data are taken from the literature or generic models are used, they should be made compatible or be properly parameterised, referring to the same waste composition (mainly carbon and water content of bio-waste, but also pollutants, such as metals, etc.).

¹⁰⁴ Farrell, M., Jones, D.L. (2009). *Critical evaluation of municipal solid waste composting and potential compost markets*. Bioresour. Technol. In press.

¹⁰⁵ Trine Lund Hansen (2005). Quantification of environmental effects from anaerobic treatment of source-sorted organic household waste. Ph.D. Thesis, Institute of Environment and Resources, Technical University of Denmark.

4.3 LCA modelling limitations

Some specific aspects should be carefully considered when performing an LCA of bio-waste management. In particular, the following aspects may be difficult to quantify and consider in the LCA modelling. These include:

- Any relevant qualitative information (since qualitative information poses inherent difficulties to integrated comparative assessments as required here, unless they have a choice or options character and can hence be addressed in scenarios. Qualitative information can however be integrated into the subsequent decision process as additional information). Care needs to be taken to not overly weigh qualitative information or a lack of quantitative information on aspects such as e.g. on soil improvement effects of compost. Also here scenarios and reasonably best/worst case scenarios help to improve the decision support; see further information more below in this chapter;
- Pressures directly on humans, e.g. during exposure to waste in the working environment and accidents. These are out of the scope of classical LCA. However, a complementary analysis can provide quantitative decision support on these issues;
- Evaluation of disamenity due to local environmental consequences (e.g. noise, odour);
- Evaluation of benefits and drawbacks from waste treatment products, especially accounting for environmental effects from use on land of compost and (composted) digestate.

Of the above, the waste-specific issues of compost benefits on land/soil will be further addressed here:

Accounting of environmental effects from use of compost on land

Boldrin (2009)¹⁰⁶ stresses that it is necessary, to develop further the LCA methodology in order to correctly incorporate environmental aspects of utilization of compost on land and precisely:

- To define balanced characterization factors¹⁰⁷ regarding the toxicity of heavy metals in soil, taking into account their concentrations and the thresholds of specific compounds rather than only their amount.

¹⁰⁶ Alessio Boldrin (2009). Environmental Assessment of Garden Waste Management. Ph. D Thesis, Institute of Environment and Resources, Technical University of Denmark.

¹⁰⁷ Emissions contributing to an environmental issue are converted into a common unit (e.g., kg CO₂-eq. for global warming or kg SO₂-eq. for acidification) using characterisation factors (e.g., for looking at global warming over a 100-year time frame, 1 kg of methane is equivalent to 25 kg CO₂)

- To establish a methodological framework for including the potential benefits of compost application on the soil quality and, more precisely, the following aspects: increased content of organic matter (better structure, better water retention, reduced erodability, better aeration and, therefore, better crop growth,), reduced need for pesticides, enhanced hydraulic retention, and improved workability.
- To study the potential diverging effects on the soil quality resulting from application of compost from waste and from digestion residues. The long-term effect of digestate application on soil biodiversity, soil and plant health, soil physical properties is not sufficiently known.

Concerning the *"toxicity aspects of the application of compost on land"*, The European Compost Network (ECN e.V.) states¹⁰⁸ that *"accumulation and toxic effects stemming from the continued application of compost is already well known and documented and can be found in the literature. It can be shown, that the application of compost produced from source separated organic household and green waste would not affect the long term multifunctional use of soil and no negative impacts on the soil/water/plant system can be expected"*.

For the time being it is recommended to build the main part of the decision support on known and quantifiable effects (such as covered in an LCA and related quantitative analyses) and include qualitative and other not (yet) quantifiable effects only in cases where the quantitative analysis cannot yield a clear decision support, noting carefully the relevance of such issues and giving a balanced perspective.

4.4 Guidance to model specific modules

4.4.1 Impacts of collection

In general, waste collection activities have a relatively small pressure on the environment compared to the pressures / benefits of waste treatment / valorisation. However, source separated collection is essential to obtain high quality materials from AD and SC processes that can be safely recycled on land and improves the overall environmental performance of the treatments.

To collect 1 tonne of organic waste from households, a diesel collection truck rides for about 10 km in urban areas, compared to a more typical value of about 70 km in rural areas¹⁰⁹. Driving 1 km leads to the emission of about 1.6 kg of CO₂ for the whole truck. Hence, about 110 kg of CO₂ are emitted to collect 1 tonne of organic waste from households in rural areas (16 kg in urban areas). This emission may be

¹⁰⁸ Comment received from the European Compost Network as part of the invited experts' consultation of this document.

¹⁰⁹ Quoted in: BIO-Intelligence Service and Ecobilan-PWC (2001). Déchets ménagers: leviers d'amélioration des impacts environnementaux. Study performed for ADEME and Eco-Emballages

compared to about 500 kg of CO₂, which are emitted from full degradation of the carbon in one tonne of bio-waste (based on average chemical composition¹¹⁰).

This picture is in this case not relevantly changed when considering other environmental pressure indicators. Thus, especially in urban areas, source separated collection does not significantly contribute to emission of greenhouse gases. Therefore, a simplified modelling is appropriate when performing an LCA including collection, unless waste collection was the specific focus of the analysis, of course.

Moreover, the impacts of source separated collection are often partly or fully compensated by reducing the frequency of MSW collection. In this respect, Ricci (2003)¹¹¹ points out that:

“An optimised collection system for wet biodegradable wastes will result in so low amounts of putrescent materials in the residual wastes that collection frequencies for these wastes may be reduced, even to the extent that the increased collection costs for wet biodegradable wastes are completely offset by cost savings in the collection of residual wastes. Data for the precise size of these costs savings are still limited, but the net additional costs for separate collection of wet biodegradable wastes are unlikely to exceed the additional cost of separate collection of other materials.”

In case source separated collection of organic waste replaces a collection of MSW (e.g. once a week instead of twice a week), there are no significant additional impacts. This means the benefits of a centralised treatment are fully conserved in rural areas. Climate plays an important role when it comes to lowering collection frequency (more frequent in warmer countries as spontaneous putrefaction starts faster).

4.4.2 Biogas valorisation

Special attention should be paid to the following parameters:

- Is there a continuous demand for heat all year (24/24h, 7/7)? If not, only consider the period when biogas is actually valorised, unless additional uses can be identified and served;
- If power is produced locally using biogas, its efficiency should be compared to the efficiency of the alternative power plants, i.e., compared to what alternative is effectively being replaced;
- The impacts of biogas treatment should also be modelled (e.g., removing moisture, CO₂, H₂S and others);

¹¹⁰ The elemental composition of the organic fraction of municipal solid waste (MSW) is constant C₅H_{8.5}O₄N_{0.2}, source: " Stoichiometry of the Aerobic Biodegradation of the Organic Fraction of Municipal Solid Waste ", Ewa Liwarska-Bizukojc and Stanislaw Ledakowicz, in Biodegradation, Volume 14, Number 1 / January, 2003

¹¹¹ Ricci M. (2003). Economic assessment of separate collection cost: tools to optimise it and the advantage of operative integration. Notes for the ECN Workshop, Barcelona, 2003.12.15-16.

- Losses and emissions due to flaring should be accounted in case of discontinuous biogas use (except when there is sufficient storage capacity); other losses during capture, storage, and transport should be accounted since they can significantly affect related decisions;
- Upgrade biogas to vehicle fuel.

Typical composition of biogas is¹¹²:

- 50-70% in volume methane (CH₄);
- 30-50% in volume carbon dioxide (CO₂-biogenic);
- About 1% of nitrogen (N₂);
- A variety of trace compounds, partly hazardous.

Whenever possible, values of the actual biogas composition should be used, based on the actual composition of the organic waste (mainly green waste, kitchen waste, industrial organic waste, etc.).

4.4.3 Incineration

Key aspects of incineration in Waste to Energy (W-t-E) plants are obviously the efficiency of energy recovery process and the composition of the bio-waste. When LCA is applied at a local scale for a specific W-t-E plant, plant-specific data should be used and the specific waste properties (mainly the net calorific value) should be considered.

The main technical characteristics of a W-t-E plant that significantly influence the overall environmental performance are discussed below:

- a) Pollutant abatement technology: dry flue gas cleaning system, hybrid wet-dry flue gas cleaning system, or wet flue gas cleaning system. The FGC (Flue Gas Cleaning) type is chosen through the well defined Integrated Approach of the Industrial Emissions Directive, which includes the question of FGC energy consumption and production of residues for the local situation. This mainly determines whether water emissions¹¹³ are present and the actual use of reactants.

¹¹² Cemagref – INRA – CReeD – Anjou Recherche – Ecobilan – Orval (2005) Impact environnementaux de la gestion biologique des déchets – Bilan des connaissances. Study performed for ADEME (French Environment Agency)

¹¹³ In many countries, plants are required to evaporate their wastewater in the Flue Gas cleaning, hence, ensuring that no water is discharged to the environment.

The selection of the technology only affects air emissions in a limited way as they all need to meet the severe requirements of the incineration directive (2000/76 of December 4, 2000). There are also some indirect effects (production of NaHCO_3 , CaO , NH_3 , Activated Coal, and water emissions from wet cleaning system), but they lead to minor impacts in case of bio-waste incineration (no or very low halogen input, no or very low heavy metals, etc.).

- b) NO_x removal: NO_x removal technology can be used or not. The two types of technologies are: selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR). NO_x removal technologies dramatically reduce NO_x emissions, but they also consume energy and reactants (ammonia).
- c) Energy efficiency. Energy can be exploited:
 - As electricity and/or steam (the distribution of the energy yield among electricity and steam is plant-specific and can vary considerably);
 - As hot water and for use in district heating.

The energy efficiency (gross production of heat and electricity related to energy input) of the W-t-E plant varies greatly among plants and over the course of a year. Annual variation is usually related to variations in ambient temperature, which influence the need for district heating, and seasonal changes of waste composition. However, the energy recovery can be partially increased by adjusting the amount of waste incinerated. Nevertheless, this is often not applied in practice because:

- Most W-t-E plants are saturated and need to be run at maximum capacity. If it is not the case, main maintenance operations, requiring stopping the furnace, can be concentrated in the summer period;
- This would require intermediate storage of the waste during the summer season (this means additional land use and extra costs). However, this is difficult with biodegradable waste. In Sweden intermediate storage is not uncommon during summertime due to much lower heat demand in the district-heating network during that period. Biodegradable waste (e.g., wood) is stored though bio-waste (e.g., food waste) is generally treated directly.

The surplus of energy that is exported from a W-t-E plant greatly depends on the energy-content of the waste and on the energy recovery process. It also depends, but to a much smaller extent, on the kind of abatement technologies used (those technologies are selected according to the pollutant concentration values to be achieved. Correct consideration of these technologies and the plant's related energy consumption (including additional fans required by wet scrubbers) is necessary.

Permanent or, near-permanent, use of the heat generated is thus crucial for calculation of plant energy efficiency. An important question is: "*Is there a continuous demand for heat all year and day and night?*" If not, valorisation should be only accounted for the period where biogas is actually valorised, unless additional uses can be identified and served. Industrial users are generally more stable on an annual basis.

d. Plant saturation:

Most W-t-E plants are saturated and need to be run at maximum capacity.

If the plant is not operated at full capacity (but this is seldom the case), source separated collection of biodegradable waste means less bio-waste is incinerated, resulting in lower emissions and lower energy recovery. Any additional treatment of bio-waste has little effect on bottom ash production (because bio-waste contains very little inert material).

If the plant is operated at full capacity (i.e., some waste has to be landfilled because of lack of capacity), source separated collection of biodegradable waste liberates incineration capacity in the plant. In practice, the liberated capacity is much lower than the weight of the derived biodegradable waste because biodegradable waste has a low net calorific value (around 2-4 MJ/kg compared to 9-10 MJ/kg for MSW). Typically, the liberated plant capacity is on the order of 1/3-1/5 of the weight of the biodegradable waste collected separately. This should be considered when modelling the effects of removing bio-waste from W-t-E plants.

Parameterised W-t-E plant models can help to quickly obtain accurate data for a specific plant; using the plants technical characteristics, waste characteristics and management strategy (as detailed above) as input parameters. Modelling avoids the requirement of collecting actual emission data.

4.4.4 Landfill

The overall environmental performance of a landfill site is very much variable. It depends on the specific performance in terms of gas / leachate collection and treatment efficiencies, emission levels, energy recovery efficiency, effectiveness of the barrier systems, etc. When LCA is applied to a specific landfill site, site-specific data should be used as far as possible, while generic, average data should be used only to amend eventual data gaps.

Similar as for W-t-E plants, parameterised landfill models allow to reduce the effort to obtaining technical characteristics of the specific site (see preceding paragraph) and its management parameters, instead of collecting all detailed data on emissions and consumables.

Life cycle inventory data on average bio-waste landfilling (differentiated for different regions of Europe) are currently provided in the ELCD database¹¹⁴.

4.4.5 Key methodological issues

When conducting LCAs on bio-waste, two main methodological issues are related to biogenic carbon and time frames; these are presented in the following sub-chapters.

4.4.5.1 Biogenic carbon

The ILCD Handbook¹¹⁵ recommends to inventory and to assess the biogenic and fossil CO₂ and CH₄. Both uptake of CO₂ from the atmosphere and the release of both fossil and biogenic CO₂ are assigned characterisation factors for the impact assessment. The lack of knowledge whether CO₂ or CH₄ emission is biogenic or fossil does not render the results erroneous.

4.4.5.2 Time-limited carbon sequestration and time frames

When performing an LCA, the choice of time-frames to consider should be made as a part of the goal definition and scoping section.

The ILCD Handbook recommends:

- To inventory as:
 - classical elementary flows, all emissions that occur within the next 100 years from the year of the analysis.
 - long-term emissions, all emissions that occur after 100 hundred years.
- To inventory flows for biogenic carbon dioxide and methane, but also for other, fossil greenhouse gases (e.g. nitrous oxide) with delayed emissions can be developed analogously. These are to be inventoried as special elementary flows (storage/delayed emission) for each contributing substance. However, since LCA has generally an indefinite impact perspective, carbon storage and delayed emissions are not considered for normal LCA studies, but only for studies (e.g. methodological) that explicitly require this inclusion in the goal definition of the study.

¹¹⁴ <http://lct.jrc.ec.europa.eu/assessment/data>

¹¹⁵ <http://lct.jrc.ec.europa.eu/publications>

- To calculate, present and discuss the emissions beyond 100 years apart from the general LCA results calculation and aggregation, to account for the inherent higher uncertainty of emissions beyond or even well beyond 100 years into the future.

Annex: Relevant European legislation and policies

Key target audience:

- LCA experts in the area of waste management
- Waste policy makers and waste managers on national and sub national level

Purpose:

- To provide an overview of the most important European legislation and policies that affect the management of biodegradable waste.

Landfill Directive (1999/31/EC)

Objectives

Council Directive 1999/31/EC from 26th April 1999¹¹⁶ aims to prevent or reduce as far as possible negative effects on the environment from the landfilling of waste:

- by improving the overall operating conditions of landfill sites; and
- by introducing stringent technical requirements for waste

Content

The Directive is intended to prevent or reduce the adverse effects of the landfilling of waste on the environment, in particular on surface water, groundwater, soil, air and human health. With that view, it notably sets requirements for all classes of landfills, including water control and leachate management, protection of soil and water, and gas control.

Directive 1999/31/EC also demands that Member States introduce national strategies that aim to progressively reduce the quantities of biodegradable waste landfilled. In this way, the total quantity (in weight) of biodegradable municipal waste landfilled needs to be reduced respectively to:

- 75 % in 2006
- 50 % in 2009
- 35 % in 2016

of the total municipal waste produced in 1995 or for the final year before 1995 for which standardised EUROSTAT data are available.

¹¹⁶ Entered into force on 16.07.1999

The Directive states that the aforementioned objectives can be achieved by recycling, composting, biogas production or materials/energy recovery (art. 5, 1.).

Waste Framework Directive (2008/98/EC)

Objectives

The Directive aims to set a framework for waste management in the EU, promoting prevention, reuse and recycling, including energy recovery as a recovery activity within a revised waste management hierarchy

Content

Waste definition

The definition of 'waste' has been significantly clarified in the revised WFD through specific articles that formally introduce the concepts of 'by-products' and 'end-of-waste':

The introduction of a definition of **by-products** in Article 5(1) formally recognizes the circumstances in which materials may fall outside the definition of waste. This change is intended to reflect the reality that many by-products are reused before entering the waste stream.

Article 6 introduces a definition for **end-of-waste** that recognizes the increasing importance of waste recovery.

Re-use and recycling targets

In order to comply with the objectives of this Directive, and move towards a European recycling society with a high level of resource efficiency, Member States shall take the necessary measures designed to achieve the following targets:

- To recycle or prepare for reuse 50% of household waste (such as at least paper, metal, plastic and glass from household) by 2020;
- To reuse, recycle or recover 70% of non-hazardous construction and demolition waste by 2020.

Bio-waste

Directive 2008/98/EC (article 22) also demands that Member States shall take measures, to encourage:

- The separate collection of bio-waste with a view to the composting and digestion of bio-waste;
- The treatment of bio-waste in a way that fulfils a high level of environmental protection;
- The use of environmentally safe materials produced from bio-waste.

The assessment shall examine the opportunity of setting minimum requirements for bio-waste management and quality criteria for compost and digestate from bio-waste in order to guarantee a high level of protection for human health and the environment.

Revised IPPC Directive and Industrial Emission Directive (IED)

On 21 December 2007 the Commission adopted a Proposal for a Directive on industrial emissions¹¹⁷. The Proposal recasts seven existing Directives related to industrial emissions into a single legislative instrument. The recast includes in particular the IPPC Directive and the waste incineration Directive (WID – 2000/76/EC). The latter will be repealed in 2014.

The IPPC Directive¹¹⁸ established a set of common rules for permitting and controlling industrial installations - it has recently been codified (Directive 2008/1/EC). This directive lays down the main principles for the permitting and control of installations based on best available techniques (BAT). It currently covers biological treatment of organic waste only if it constitutes pre-treatment before disposal.

In the ongoing revision the Commission has proposed covering all biological treatment of organic waste above a capacity of 50 tonnes per day.

The Directive on industrial emission (2010/75/EC), the so-called Industrial Emission Directive (IED), has been adopted in November 2010. It lays down rules on integrated prevention and control of pollution arising from industrial activities as well as rules designed to prevent or reduce emissions into air, water and land, and to prevent waste generation.

BREF Waste Incineration

Best Available Technologies (BAT) are described in a BREF document (BREF = Bat REF document). The BREF on Waste Incineration is available at: <http://eippcb.jrc.es/reference/wi.html>

This BREF covers installations for the incineration of hazardous and municipal waste. In addition to the thermal treatment stage of the installation, this BREF also covers:

- The receiving, handling and storing the waste;
- The effect of waste pretreatment on the selection and operation of waste incineration processes (in some cases, this includes a description of the techniques applied);
- Applied flue-gas treatment techniques;

¹¹⁷ Proposal for a Directive of the European Parliament and of the Council on industrial emissions (integrated pollution prevention and control) (Recast) [COM(2007) 843 final] [SEC(2007) 1679] [SEC(2007) 1682]

¹¹⁸ Directive 1996/61/EC

- Applied residue treatment techniques (for the main residues commonly produced);
- Applied waste water treatment techniques;
- Some aspects of energy recovery, the performance achieved and the techniques used. Details of electrical generation equipment, etc., are not included.

Waste Incineration Directive (2000/76/EC)¹¹⁹

The waste incineration directive (WID) regulates the technical requirements for the operation of incineration plants, including emission limit values for selected potential contaminants (e.g., NO_x, SO_x, HCl, particulates, heavy metals and dioxins) in order to prevent, as far as practicable, negative impacts on human health and the environment. It is relevant for bio-waste treatment as it covers incineration of most of bio-waste (including mixed waste containing biodegradable fractions). The Integrated Pollution Prevention and Control (IPPC) Directive also covers many of the plants that are covered by the WI Directive. In these cases, the WID only sets minimum obligations, which are not necessarily sufficient to comply with the IPPC Directive.

Animal By-products Regulations (2007/1432/EC¹²⁰ and 2002/1774/EC¹²¹)

This Regulations establishes detailed rules for the protection of public and animal health that apply to the use of animal by-products in biogas and composting plants. This regulation concerns “biogas and composting plants”, but in some EC member states this regulation is extended to home composting ‘plants’ (e.g., Belgium/Flanders) in order to reduce health and contamination risks.

EU Policy for Renewable Energy, Directive on Renewable Energy Sources, and COM(2010)11

The EU Policy for Renewable Energy and Directive on Renewable Energy Sources (RES) (2009/28/EC) establishes targets for total Renewable Energy Sources. Since biomass accounts for a relatively large share in total RES, this may lead to competing demands for biomass.

The RES Directive also relates to bio-waste and encourages its use to replace fossil fuels. National targets are established for the total share of energy from renewable sources. It lays down rules relating to statistical transfers between Member States,

¹¹⁹

¹²⁰ EC Regulation 1432/2007: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:320:0013:0017:EN:PDF>

¹²¹ Regulation (EC) No 1774/2002 of the European Parliament and of the Council of 3 October 2002 laying down health rules concerning animal by-products not intended for human consumption.

joint projects between Member States and with third countries, guarantees of origin, administrative procedures, information and training, and access to the electricity grid for energy from renewable sources. It establishes sustainability criteria for biofuels and bioliquids, while encouraging the use of bio-wastes, e.g. cooking oil or bio-methane, for developing so-called second-generation biofuels. The RES directive is adopted and in force; Member States transposed it on December 2010.

The RES Directive considers the use of biomass, i.e. the biodegradable fraction of products, wastes and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste, to count towards the renewable energy targets, but leaves it up to Member States to decide how certain renewable energy resources should be supported.

Also, the communication from the Commission COM(2010)11 gives recommendation for sustainability criteria to be used for biomass for electricity and heating purposes.

Commission Communication on future steps in bio-waste management, COM(2010) 235¹²²

Objectives

This to the council and the European Parliament is related to future steps in the bio-waste management in the European Union. It explains the steps considered necessary by the Commission at this stage for optimizing the management of bio-waste.

Content

In particular, the Communication:

- Draws conclusions from the Commission's analysis;
- Provides recommendations on the way forward to reap the full benefits of proper bio-waste management;
- Describes the main potential courses of action at EU and national level and how to best implement them.

Green Paper on management of bio-waste¹²³

Objectives

The Green Paper aims at:

¹²² Communication from the commission to the council and the European parliament on future steps in bio-waste management in the European Union (COM(2010)235))

¹²³ Report on the Commission Green Paper on the management of bio-waste in the European Union [2009/2153(INI)] - Committee on the Environment, Public Health and Food Safety. Rapporteur: José Manuel Fernandes

- Exploring options for the further development bio-waste management; and
- Stimulating a debate on the possible need for future policy action, seeking views on how to improve bio-waste management in line with the waste hierarchy, possible associated economic, social and environmental gains, as well as the most efficient policy instruments to reach this objective.

The Paper is intended to stimulate a debate among stakeholders and help the Commission assess the need for additional EU action.

Content

The Green Paper includes an overview of current bio-waste management practices in the EU, and looks at the benefits and drawbacks of these methods, taking into account environmental, economic and social issues.

The Paper also looks at the impact of existing regulatory measures. Bio-waste management is already subject to a number of EU and national legislative measures. This includes:

- Obligatory diversion from landfills (Landfill Directive);
- Encouragement of recycling (under the new Waste Framework Directive);
- Incineration and composting (Incineration Directive, IPPC Directive, and Animal By-Products Regulation);
- Product standards and requirements (Organic Farming Regulation, the EU Ecolabel requirements for compost, national standards).

The Green Paper will also consider the need for new legislation which could help to direct more bio-waste towards recycling and energy recovery.

Strategy on soil protection

The Commission adopted a Soil Thematic Strategy (COM (2006) 231) and a proposal for a Soil Framework Directive (COM (2006) 232) with the objective to protect soils across the EU.

The draft Soil Framework Directive imposes the obligation for member States to design programmes of measures to combat organic matter decline (Article 8). Member States are requested to draw up, at the appropriate level, a programme of measures including at least the following: risk reduction targets, appropriate measures for reaching those targets, a timetable for the implementation of those measures and an estimate of the allocation of private or public means for the funding of those measures.

In Article 10 of its resolution¹²⁴ on this proposal, the European Parliament requires that “the Commission shall present a proposal for a bio-waste Directive setting quality standards for the use of bio-waste as a soil improver.”

This requirement can be seen in the light of a trade-off identified in the EU Soil strategy:

- On the one hand, compost is identified as a tool to fight the decline of organic matter in soils;
- On the other hand, there is the need to prevent soil contamination.

Energy issues and climate change

The European Climate Change Programme considers promoting organic input on arable land (crop residues, cover crops, farm yard manure, compost, sewage sludge) as a tool to reduce Greenhouse gas emissions¹²⁵.

¹²⁴ European Parliament legislative resolution of 14 November 2007 on the proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC (COM(2006)0232 – C6-0307/2006 – 2006/0086(COD)) - P6_TA(2007)0509 – art. 8a (amendment 66)

¹²⁵ http://ec.europa.eu/environment/climat/pdf/finalreport_agricsoils.pdf

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Abstract

It is crucial to establish priority actions to optimise the management of the large quantities of bio-waste produced yearly in Europe. These efforts are expected to generate environmental benefits as well as financial savings and social advantages.

This guidance document provides anyone involved in bio-waste management with the key principles to improve their decision-making process in the management of bio-waste by using Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA). The main focus is on the environmental pillar of sustainability. In particular, a number of different options for bio-waste management are considered (e.g., composting, anaerobic digestion, incineration) and guidance is given on how to assess and compare their environmental performance using a life cycle approach.

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